

ESTABLISHMENT METHODS AND COMPARATIVE PERSISTENCE
OF FIVE TROPICAL LEGUMES IN GRASS SODS

By

DARCI T. GOMES

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By

Darci T. Gomes

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The main purpose of the research was to determine the effect of several seedbed-preparation methods on the establishment and persistence of five tropical legumes in two tropical grass sods. As an additional objective, the effect of the legume inclusion in the grass sods on the quantity and quality of the forage produced by the mixtures was also studied.

Two small-plot field experiments were conducted at the Agricultural Research Center, Fort Pierce, Florida, from 1 July 1976 to 30 Sept. 1978. The two experimental areas used were 3-year-old stands of 'Pangola' digitgrass (Digitaria decumbens Stent.) and 'Bigalta' limpograss (Hemarthria altissima (Poir.) Stapf et C. E. Hubbard).

Five seedbed preparation methods were compared: no tillage, light disking followed by broadcasting of the seeds, seeds broadcast followed by disking, sod-seeding, and complete seedbed preparation. Five legumes were tested: 'Siratro' (Macroptilium atropurpureum (DC.) Urb.), centro (Centrosema pubescens Benth.), joint vetch (Aeschynomene americana L.), 'Verano' Caribbean stylo (Stylosanthes hamata Taub.), and 'Florida' carpon desmodium (Desmodium heterocarpon (L.) DC.). The treatments were arranged in a split-plot design with five replications.

Even though all legumes tested established quite well in mixture with Pangola digitgrass, Siratro and joint vetch were the only ones that persisted and actually made a substantial contribution to the total dry-matter yields of the Pangola-legume mixtures during the growing seasons of 1977 and 1978. A Pangola-legume mixture containing either 50% Siratro or 50% joint vetch provided twice the dry-matter, and four to five times the crude protein yields of Pangola digitgrass grown alone.

In the Bigalta limpograss experiment, as in Pangola digitgrass, all legumes established quite well. Joint vetch, carpon desmodium, and centro performed better than the other legumes. The persistence of these legumes was most likely due to their better adaptation to the poorly drained soil conditions of the experimental area. The legume contribution to total dry-matter yields of Bigalta-legume mixtures in the 1977 and 1978 growing seasons was not very marked. The highly competitive growth characteristic of Bigalta is believed to be the main reason for the low legume contribution to yields from the mixtures.

Results of the experiments suggested that seedbed treatments might not be as critical for persistence as it is for establishment of the legumes. In the year of establishment, all legumes were significantly affected by the type of seedbed preparation and there was a substantially higher number of plants in some treatments than in others. These differences, however, were not evident 1 and 2 years after establishment when all legumes tended to reach a rather uniform population in all seedbed-preparation treatments. Joint vetch was the only legume for which seedbed treatments were still exercising their influence in the 1978 growing season.

INTRODUCTION

In south Florida, improved tropical grass pastures substitute for or complement the poor quality, native pine Flatwoods range as a part of a feeding system for beef cattle.

'Pangola' digitgrass (Digitaria decumbens Stent.) is widely used as an improved tropical pasture grass in south Florida. In addition, the use of 'Bigalta' limpoglass (Hemarthria altissima (Poir.) Stapf et C. E. Hubbard) is increasing because of its adaptation to the many wet or frequently flooded areas. These tropical grasses, when growing alone, require high N fertilization if their production and quality are to be maintained. The high cost of N fertilizers and possible leaching losses from coarse-textured soils have stimulated researchers to search for alternatives to N fertilized grass pasture systems.

A viable alternative to N fertilization is a tropical legume-grass pasture. The inclusion of a legume can substantially increase the quantity and quality of forage produced by the pasture.

Deficiencies of dietary protein are known to depress intake of dry-matter by ruminant animals. When the crude protein content of tropical grasses falls below about 7.0% (Milford and Minson, 1965), dry-matter intake is depressed. Thus, the inclusion of a legume in a grass pasture makes an important contribution to the quality of the pasture by maintaining adequate protein levels in the feed on offer. The legume, among other attributes, will act as a supplement and maintain crude protein above the critical level, resulting in increased intake of the associated grass.

According to Henzell (1968), the legume component makes little use of the available soil N. Therefore, legume yield may be considered as a bonus, since most of the soil N is used by the grass component. In addition, N fixed by the legume is made available to the associated grass after decay and mineralization of fallen leaves, roots, nodules, stubble and by recycling of N through animal excreta.

Blue (1978) stated that 155 kg/ha of N per year were needed to assure yields of about 11,000 kg/ha of oven-dry forage of 'Pensacola' bahiagrass (Paspalum notatum Flugge). Good tropical legume growth, according to Henzell (1968), can fix N amounts as high as 200 kg/ha per year. Consequently, tropical legumes can supply N enough to obtain reasonable yields of most tropical grasses.

It becomes evident that a stable grass-legume pasture system would constitute the ideal for every beef-cattle enterprise in the tropics. The wide range of environmental conditions occurring in the different areas within the tropical region, however, has made it impossible for anyone to determine and actually prescribe the species, establishment methods, and management recommendations for maintaining a balanced grass-legume pasture.

The present study was undertaken with the purpose of providing additional information on establishment techniques and persistence of tropical legumes in established Pangola and Bigalta grass sods. An additional objective was to determine the contribution of each of the legume species tested to the quantity, crude protein, and IVOMD of forage produced by the components of the mixtures.

REVIEW OF LITERATURE

Tropical Legume-Grass Mixtures in Pasture Systems

Animal production on pastures is determined by quantity and quality of the forage available to the grazing animal throughout the year. In tropical regions, and under natural pasture conditions, very rapid wet-season growth normally results in a large amount of forage accumulation. Typically, the grass forage has an adequate N concentration at the beginning of the growing season, decreases rapidly as the season progresses, and reaches nutritionally deficient N levels before flowering time. In addition to the low N content in native pasture species, predominantly grasses, there is a progressive increase in fiber and decreases in digestibility, intake and mineral composition. The use of N fertilizer to overcome the deficiency of N generally is not economical. Furthermore, there are few beneficial effects of N applications on forage quality improvement due to the dilution of the N as a result of rapid growth in the wet season and to the low N extraction capacity during the dry season (Paladines and DeAlba, 1963).

Grass-legume mixtures may compare favorably with grass growing alone with or without N fertilization. In Florida, Kretschmer et al. (1973) obtained annual dry-matter yields of 12,430 kg/ha with Pangola-'Greenleaf' desmodium (Desmodium intortum (Mill.) Urb.) mixtures which were significantly higher than 2,560 and 9,400 kg/ha obtained with Pangola growing alone and receiving, respectively, 0 and 126 kg/ha of N. They also

reported that 98, 110, 135, and 185 kg/ha N per year would have to be applied to Pangola growing alone (assuming 100% utilization of applied N) to obtain the yields of mixtures of this grass with Townsville stylo (Stylosanthes humilis H.B.K.), Siratro, carpon desmodium, and Greenleaf desmodium. In another experiment by the same author (Kretschmer, 1968), he obtained 700 kg/ha of crude protein per year with a Townsville stylo-Pangola mixture and only 179 kg/ha from Pangola growing alone without N fertilizer.

Introduction of legumes into the existing natural pastures seems to be one of the most feasible alternatives for improvement of these pastures. The techniques to be used, species to be chosen, and other agronomic considerations will depend upon specific sets of environmental conditions. In an extensive area of northern Australia, productivity of natural pastures has been increased by oversowing Townsville stylo into the native speargrass (Heteropogon contortus (L.) Beauv. ex Rhoem and Schult.) after burning. By introducing the Townsville stylo into the native pasture without fertilizer application, stocking rates and liveweight gains per hectare were doubled (Graham and Meyer, 1972). Further increases in beef production were obtained when superphosphate was applied to the legume-oversown natural pastures.

Norman and Stewart (1964) showed that the gain per head of cattle grazing Townsville stylo-grass pastures, at Katherine in Northern Australia, was linearly related to the proportion of legume in the pasture. In another study conducted in the same area by Norman (1970), animal liveweight gain during the dry season was related to the number of days during which the animals had access to the legume. In 2 years, animals on grass pastures gained 60 kg/head, while those grazing grass-legume pastures gained 280 kg/head. During 112 days of the dry season,

the first group lost almost 40 kg/head, while the second gained 60 kg/head.

Sanchez (1977) pointed out that if any considerable improvement in productivity is to be expected from native pasture areas in tropical America, it will be necessary in most cases to replace the native grasses with improved species before introducing tropical legumes. In the Pucallpa area of Peru, Santhirasegaram (1975) has shown that the use of a mixture of molassesgrass (Melinis minutiflora Beauv.) and stylo (Stylosanthes guianensis (Aubl.) Sw.) receiving 50 kg/ha of P as ordinary superphosphate, doubled the stocking rate, doubled the calving rate, tripled the annual liveweight gain, and reduced by half the age at which the animals attained slaughter weight. Paladines and Leal (1978) reported that in the unimproved savannas of the Llanos Orientales of Colombia annual liveweight gains of 6 to 19 kg/ha are obtained. These gains were increased to 58 kg/ha in Brachiaria decumbens Stapf. - stylo pastures. In the dry season, daily liveweight gains of up to 500 g/animal/day were obtained on the legume based pasture, while on the unimproved pasture animals lost from 150 to 350 g/animal/day.

Among the advantages most often given for using legume-grass mixtures in place of N-fertilized pastures is the often low N recovery from applied N to the grass. Under grazed pasture conditions it would be reasonable to assume a high recovery through recycling, but this is not always observed. Henzell (1972) working on Ultisols in Queensland, was able to account, for only 40% of the 374 kg of N/ha/year. He measured the amount used by cattle, the amount accumulated in standing herbage, and the amount present in the top 75 cm of the soil. Blue (1973) studied the apparent recovery of applied N in harvested Pensacola bahiagrass grown on Leon

fine sand, a Spodosol. The N recovered from an annual application of 112 kg/ha of N ranged from 30 to 57% over the 6-year study period. The author suspected that denitrification would be the major mechanism of N losses observed under the soil conditions of this experiment. In Leon fine sand in the summer rainy season the water table is high, plant decomposition is fast, the anaerobic conditions created by frequent high water tables could enhance denitrification.

Nitrogen fixation capacity of efficient legume-rhizobium associations is reported to be similar to that of temperate legumes (Henzell and Norris, 1962; Jones, 1972). Jones (1972) has shown that the amount of N fixed is highly correlated to the dry-matter production of the legume. Whitney et al. ((1967) reported that approximately 4 tons/ha of legume dry-matter yield were needed to fix 100 kg N/ha a year. Direct transfer of legume-fixed N amounted to a rather small proportion of the total N fixed. Greenleaf desmodium transferred only about 5% of the total N fixed to the tops of the associated Napiergrass (Pennisetum purpureum Schumach). Whitney (1970) reported that there was a 53% N transfer, however, in a 3-year old Pangola-Greenleaf desmodium mixture. These values were calculated by differences in N uptake of the grasses in the presence or absence of legumes, and include top and root decomposition. His results suggested that leaf fall and root decomposition as well as nodule decomposition are the main mechanisms of N transfer from the legume to the associated grass. Vicente-Chandler et al. (1974) stressed the importance of these factors on indirect N transfer mechanisms under pasture conditions, since about 80% of the forage diet N ingested by adult beef cattle is returned to the pasture field via urine and feces.

There are other benefits of having a legume included in a pasture. Legumes often are more tolerant to drought and produce green feed even during the dry season, when feed is scarce. Most grasses are dormant during this period (Gusman, 1975). Also, legumes will maintain adequate nutritive values for a longer period of time than most tropical grasses (Milford and Haydock, 1965). According to Minson and Milford (1967) the critical level of crude protein (CP) required in a pasture, before intake is reduced by N deficiency, is estimated to lie between 6.0% and 8.5%. Even well-fertilized improved tropical grasses have values well below this at late growth stages (Moore et al. 1970; Ventura et al. 1975). The CP concentration in dry-season forage in natural pastures may decline to less than 3.8% and even with highly selective grazing the concentration in the ingested feed may be below the critical 6 to 8% level (Robertson, 1974). Tropical legumes maintain a higher CP level during the dry season, or with advanced maturity (Milford and Haydock, 1965). Minson (1971) suggested that the high animal responses associated with the inclusion of legumes into grass pastures is most likely due to the increase in dry-matter production of the pasture and the higher nutritive value of the legume. T'Mannetje (1974), however, disagreed with Minson (1971), pointing out that attempts to relate animal live-weight gains (LWG) to total dry-matter production of grass-legume mixtures have failed, even though LWG has shown to be quite highly correlated to legume content in pastures (Norman and Stewart, 1964). T'Mannetje (1974) further stated that total green material is the best available predictor of LWG. Total green material, green grass, and green legume all showed good correlation with LWG, while no relation was found between LWG and total dry-matter production. The author pointed

out that selective grazing is the only possible explanation for high performance of grazing animals during dry-season periods in the tropics, this being observed mainly when available forage exceeds animal requirements.

Establishment of Tropical Pasture Legumes in Existing Grass Sods

Forage crop specialists generally agree that the establishment period is from seeding to the end of the first harvest year. Herriot (1958) divided the establishment period into three phases: (1) seedling establishment - 4 to 8 weeks; (2) young plant establishment - from 4 to 8 weeks until the end of the seeding year; and (3) final establishment - the plant establishment manifested into and from "(2)" until the end of the first harvest year. The same author defined establishment of a particular crop species as being that proportion of viable seeds sown which give rise to fully established plants.

A great number of factors will influence the establishment phase of pasture species. These factors may be either inherent to the species or related to environmental conditions. The species-inherent factors most often reported as affecting establishment are seed size, purity, and viability. The environmental conditions include soil moisture, temperature, solar radiation, and soil nutrients. Management practices, like weed control, seed inoculation, seed scarification, depth of planting, and seed-bed preparation are also important. Insects, nematodes, and diseases can also affect the establishment phase, many times resulting in establishment failures.

Effect of Seed Purity, Viability, and Seed Treatments on Germination

Seed purity and viability, according to Leach et al. (1976), are two very important species-inherent factors which will determine to a great extent the chances of attaining successful pasture establishment. Since the biological purpose of a seed is conservation and dissemination of the species, it should germinate when conditions are suitable. This, however, may not happen under natural field conditions, because seed germination might be prevented by various "dormancy" mechanisms, (Quinlivan, 1971a). The dormancy mechanism which prevents water movement through seed coats is known most frequently as "impermeability" (Rossiter, 1966) or "hardseededness," and seeds with this characteristic are referred to as 'impermeable' or "hard" seeds (Quinlivan, 1971a). This mechanism differs from "post harvest", "physiological" or "embryo" dormancy, which are seed-inherent characteristics (Rossiter, 1966).

Hardseededness may or may not be a desirable characteristic for establishment and persistence of tropical legumes, depending upon environmental conditions. Quinlivan (1971b) has indicated that hardseededness is the main mechanism regulating the germination, and hence persistence of many annual tropical legumes. Townsville stylo (Stylosanthes humilis H.B.K.), is very hardseeded, especially when harvested early in the season, and seeds are often scarified before being planted. Holm (1973) pointed out that in areas where rainfall is considered marginal for Townsville stylo growth, seeding with scarified seeds may lead to "false starts." Intact pods which usually have a much higher hard seed content, however, are less susceptible to false starts and result in better stands in those areas. On the other hand, under environmental conditions characterized by good rainfall during the establishment phase, reduced

hardseededness may be desirable because more seeds will germinate and establish more rapidly.

Hardseededness has been reported to occur with several of the commonly used tropical forage legumes. It occurs in joint vetch (Aeschynomene americana (L.) (Hanna, 1973), 'Verano' Caribbean stylo (Stylosanthes hamata (L.) Taub.), in stylo (Stylosanthes guianensis (Aubl.) SW.), and in five other Stylosanthes species (McIvor, 1976). Also, centro (Centrosema pubescens Benth.) (Humphreys, 1974) and 'Siratro' (Macroptilium atropurpureum (DC.) Urb.) (Phipps, 1973) are hardseeded.

The use and success obtained with mechanical and other means of reducing hardseededness will vary with the legume species under consideration. Humphreys (1974) obtained good results in overcoming hardseededness in centro by soaking seeds for 30 minutes in boiling water; after that, the seeds were washed in cold water and dried. Humphreys stated that this procedure would be used only when soil moisture was expected to be adequate for germination and seedling establishment. Untreated Siratro seed increased its germination from 26.6 to 38.2% when seed was soaked in tap water for 24 hours (Mattos, 1970). In the same experiment, germination was 59.8% when Siratro seeds were mechanically scarified and 65.4% when seeds were submerged in concentrated sulfuric acid for 3 minutes. Phipps (1973) increased Siratro seed germination from 18 to 94% when soaking unscarified seeds in concentrated sulfuric acid for 15 minutes.

Brolmann (1975) recommended a dry-heat pretreatment to improve germination of stylo seed. He stated that drought, heat, and cold alternations will enhance the germination of stylo seeds in the field. Holm (1973) previously had worked with intact and dehulled Townsville stylo seed submitted to dry heat temperatures ranging from 40 to 115° C for 12 to

48 hours duration. Temperatures of 75 and 95° C markedly decreased the level of hardseededness of all seeds. A temperature of 115° C for 12 hours killed all seeds. The author recommended that sufficient heat treated, unhulled Townsville stylo seeds should be used to reduce hardseededness, yet retain sufficient hard seed to prevent total loss of establishment should conditions favor "false starts."

In Florida, establishment of joint vetch into established grass sods, has in many instances failed to succeed. Ruelke et al. (1975) attributed many of these failures to the hardseededness of the commercially available unhulled seeds which result in low germination rates in the field. Hanna (1973) reported that joint vetch seeds with intact pods were more than 90% hardseeded. Slitting the pods with a razor blade or scarification with sandpaper increased germination, three and ten fold, respectively, compared with intact pods. Ruelke et al. (1975) confirmed these results using unhulled seeds of joint vetch. Untreated, mechanically scarified, seed soaked in concentrated sulfuric acid (98.08%) for 30 minutes, and seed heated for 5 minutes in a Bunsen burner flame resulted in 5.5, 98.0, 43.0, and 43.0% germination, respectively. Field trials in which grass sod containing joint vetch seed was burned early in the spring, resulted in a substantial increase in the number of established seedlings compared to no burning (Ruelke et al., 1975). These results confirm the beneficial effects of high temperature on breaking mechanical dormancy of unscarified, intact, joint vetch seeds.

Seedbed Preparation

Proper seedbed preparation is essential for good germination and establishment of pasture crops. The type of seedbed required for tropical

legume establishment depends, among other factors, on soil type, moisture regime, and vegetation occurring in the area to be planted.

In established grass sods, grass competition is a major factor affecting successful establishment of tropical legumes. Low cost methods which will reduce grass competition without the need for full seedbed preparation are needed. Herbicide use to reduce grass competition, has been useful in tropical legume establishment. Murtagh (1963) reduced grass competition by spraying a Paspalum spp. dominant pasture with 2,2 DPA-amitrole. Good sod-seeded glycine establishment followed the herbicide application. Yields from chemically prepared seedbed were less than those from cultivated plots. However, the high yields of the cultivated plots were offset by a high weed population that did not occur in the herbicide-treated plots. This, and the lower erosion risk, could favor the adoption of chemical seedbed preparation rather than soil disturbance by cultivation. Kalmbacher (1977), in south Florida, obtained excellent stands of joint vetch, alcy clover (Alysicarpus vaginalis (L.) DC.) and hairy indigo (Indigofera hirsuta L.) when sod-seeded into 'Pensacola' bahiagrass sods previously treated with Dowpon M and Dowpon-Paraquat combinations. The "Zip-seeder" used prepares a narrow seedbed, while the simultaneously applied herbicides suppress the grass growth until the sod-seeded plants are established. Kalmbacher (1977) also found that sod-seeding + herbicide applications resulted in less injury to the permanent pasture grass, reduced soil erosion, conserved soil moisture, and allowed more uninterrupted grazing when switching from permanent to temporary pastures.

Burning the grassland prior to oversowing legume seeds is another inexpensive and quick method of seedbed preparation. According to Keya

et al. (1972) the grassland should be burned towards the end of the dry season for oversowing at the start of the rains. Burning followed by heavy grazing is often used as means of reducing competition from the competitive tall growing grasses. In Australia, Coaldrake and Russell (1969) obtained good establishment of Siratro and phasey bean (Macropodium lathyroides (L.) Urb.) by broadcasting seeds onto the ash covering of a newly burned area of forest which had been felled about 1 year before seeding time.

Improved reestablishment of annuals such as joint vetch may also occur after burning. Tang (1976) reported that a significantly larger number of seedlings of joint vetch established after burning in late winter than from disced or untreated plots. Dry-matter yields of the first summer harvest were significantly higher in burned than in other plots.

Mott et al. (1976), comparing several seedbed preparation methods, reported lower germination of Townsville stylo seeds after burning compared to native grass plots not burned. They also found that in sandy and clay loam soils the surface of burned plots dried too quickly after rainfall. The clay loam soil dried to -1 bar within 24 hours of the cessation of rainfall. Where grass cover was maintained, the soil moisture was always higher than in the burned areas. On the sandy soil, an evening rainfall of 3.5 mm falling after 2 days of heavy rainfall was not sufficient to maintain the surface soil moisture suction below wilting point at noon the following day. Stocker and Sturtz (1966) had already shown that Townsville stylo can be established on uncultivated soil surfaces and that its early establishment is actually better in the

presence of native grass cover. This was attributed to the fact that vegetation conserves moisture at the soil surface.

The degree of soil preparation required will depend on the aggressiveness of the existing grass and the seeded legume competitive ability. Tudsri and Whiteman (1977) demonstrated that there is little prospect of establishing an oversown legume into swards of grasses as aggressive as setaria (Setaria anceps Stapf ex Massey) without good seedbed preparation. If cultivation is going to be used, there is no advantage in burning or herbicide spraying prior to cultivation. Both resulted in higher grass tiller densities and consequently higher competition with the legume overseeded. The authors suggested that for the type of conditions and species which they were dealing with, heavy grazing before cultivation for oversowing appeared to be the simplest method to utilize some of the biomass available and reduce the litter. Murtagh (1972), in northern New South Wales, also found that some form of seedbed preparation was required to obtain an adequate establishment of lablab bean (Lablab purpureus (L.) Sweet). On cultivated seedbeds, the available N would be augmented by mineralization of soil N. Less N mineralization would occur with non-cultivation which could result in poor lablab seedling vigor if nodulation was delayed. It was concluded that until means of improving field nodulation are available, lablab should be sown under conditions where there is a minimum of competition from grass. Cultivation would reduce competition and increase soil N availability insuring adequate seedling growth even if nodulation is slow or ineffective at early establishment phases.

A fine seedbed preparation is not always necessary in order to obtain good legume establishment into native or cultivated grasses. Tow

(1960) obtained good establishment of glycine (Glycine wightii Verdc.) by sod-seeding it into a 'Green panic' guineagrass (Panicum maximum Jacq.) pasture. The grass stand was good, but plants were weak and showed signs of N deficiency. The glycine established well because of the slow growth of Green panic. In another experiment by the same author, sod-seeded glycine failed to establish well in a dense sod of Rhodesgrass (Chloris gayana Kunth.) due to excessive grass vigor. Roberts (1974) stated that sod-seeding and other partial cultivation techniques can be used successfully to establish legumes such as Siratro and centro into open grass swards. He did not recommend these methods, however, to establish legumes into grass swards such as carpet-grass (Axonopus affinis Chase) which form tight sods. Tothill (1974) obtained good Siratro establishment by sod-seeding into native pasture in Australia. A linkage disc sod-seeder was used and the seed was planted while simultaneously broadcasting superphosphate and towing a cultipacker roller. The tractor carried an angled blade mounted in front, riding 20 cm above the ground, to push aside fallen logs and branches. Penetration by the discs was satisfactory if soil was moist and 0.8 to 1.2 ha per hour could be seeded in this manner. The author concluded that this method of sod-seeding was more economical than prepared seedbeds even though sod-seeded plants were slower to establish. Keya et al. (1972) suggested that where natural cover is not too tall and/or dense, 'Silverleaf' desmodium (Desmodium uncinatum (Jacq.) DC.) could be successfully oversown in untreated grassland. Where grazing animals are available, the area should be grazed closely before planting. If adequate soil moisture is available after oversowing, animals should be maintained on the oversown site to trample the seed into the soil.

They should be removed after germination begins. In Mexico, Garza et al. (1972) compared: (a) full seedbed preparation, (b) disking, (c) row planting, and (d) burning for establishment of Siratro, centro, and clitoria (Clitoria ternatea L.) into a Pangola sod. They found no significant difference among (a), (b), and (c) but number of plants found in (d) treatment were significantly less than those in other treatments.

The varied results obtained with different seedbed methods for establishing tropical legumes can be attributed, in part, to environmental and edaphic factors occurring at seeding and seedling stages. Hyder and Sneva (1956) pointed out that if soil moisture is abundant a high macropore space would be desirable at seeding time, but with less moisture availability, attempts should be made to increase the micropore space and the retention of moisture. Plowing would be an adequate soil preparation method when soil moisture is good, but if soil moisture stress is likely to occur, shallow disking to loosen the surface of firmed soils and strip rolling are especially beneficial in terms of moisture retention.

McGinnies (1962) pointed out that on loose sandy soils, seedling establishment is improved by cultipacking particularly if the soil is moisture deficient. Close contact between seed and soil increases the chances of germination by facilitating water imbibition by the seeds. When soil moisture is above or at field capacity, however, there is no advantage in cultipacking. Norman (1960) affirmed that if soil moisture and temperature are favorable during germination time, seedbed preparation is of secondary importance. However, as droughty

conditions increase, the type of seedbed preparation becomes more important in determining the success of establishment attempts.

The difficulty of establishing small-seeded legumes is particularly accentuated when environmental conditions are suboptimal. Two factors most commonly associated with failure of seedlings to emerge are lack of soil moisture and improper depth of coverage of seeds. Triplett and Tesar (1960) reported that moisture conditions near the seed and initial emergence of alfalfa (Medicago sativa L.) seedlings were improved progressively by increasing planting depths from 0 to 2.5 cm and by soil compaction. When 1.5 cm of irrigation was applied after seeding, maximum average emergence was obtained from the 1 cm planting depth, showing that if moisture is not limiting the depth of planting is not critical. McGinnies (1959) in Utah, on a shallow silt loam soil, compared the establishment of 'Nordan' crested wheatgrass (*Agropyron* spp.) when seeded 2.5 cm deep, 5 cm deep, 7.5 cm deep, and surface sown. Results indicated that the 2.5 cm furrow was not better than the surface treatment, but that larger numbers of seedlings germinated from the 5, 7.5, and 20 cm deep furrows. Consequently, planting in furrows would very definitely improve establishment under conditions of soil moisture stress. Stonard (1969) confirmed these observations and stated that if a continuous stocking rate is used and normal rainfall occurs after surface sowing of Townsville stylo, the seed would be placed at the minimum necessary depth. Mechanical coverage in this case would probably place the seed at excessive depth. The author further stated that where it is impractical to drill seed to a predetermined depth, it is preferable that that seed be sown on the surface following cultivation and that further mechanical treatment be restricted to rolling.

Soil pH, Aluminum, and Manganese Toxicity

It is well known that pH per se does not restrict plant growth, except at pH values below 4.2, where the hydrogen ion concentration may stop or even cause ion release by the roots (Black, 1967). Acid soil infertility in the tropics is due to several factors including Al and Mn toxicity and P, Ca, or Mg deficiency (Sanchez, 1977).

Aluminum levels above 1 ppm in the soil solution can cause direct crop yield reduction, primarily by injury to the root system. Root development is restricted and characteristically, roots become thick and stubby with dead spots appearing on the epidermis. Aluminum tends to accumulate in the roots and impair the uptake and translocation of Ca and P. As a consequence of this, Al toxicity may induce or accentuate Ca and P deficiencies (Sanchez, 1977).

Tropical legume tolerance to Al and Mn toxicity and to Ca and Mg deficiency varies widely. Andrew and Vanden Berg (1973) reported that Townsville stylo and 'Greenleaf' desmodium (Desmodium intortum (Mill.) Urb.) are relatively insensitive to Al levels of 2 ppm in the soil solution, while alfalfa is severely affected. Glycine has low tolerance to Mn and Al (Bogdan, 1977). Greenhouse work at CIAT (Centro Internacional de Agricultura Tropical, Annual Report, 1975) showed marked Al tolerance differences among tropical legumes. The CIAT 64A accession of Townsville stylo and CIAT 118 'Verano' stylo (Stylosanthes hamata (L.) Taub.) were grown in a complete nutrient solution at pH 4.0 and containing 2 ppm Al for the first 6 weeks and 4 ppm Al for the last 4 weeks. CIAT 118 showed greatly reduced top and root growth, while 64A was unaffected. Effects of Ca and P concentrations on Al toxicity also were studied. A five-fold increase in Ca greatly reduced

Al toxicity symptoms in roots of CIAT 118. Increases in P stimulated growth of tops and roots but did not eliminate the darkening and deformation of the roots caused by the Al.

Manganese toxicity is often a problem in the tropical Oxisols and Ultisols. Manganese like Al is soluble at pH values below about 5.5 (Black, 1967). According to Sanchez (1977) soluble Mn, however, should be kept within the range of 1-4 ppm in the soil solution. This is a favorable range for plant growth in most tropical soils.

It is clearly evident that Al toxicity is the most common cause of the acid infertility of tropical soils. This toxicity can be corrected by liming to pH 5.5 to 6.0, precipitating the exchangeable Al as hydroxy-Al. Manganese toxicity also can be corrected by liming to pH 5.5 to 6.0, the range within which the solubility of Mn decreases enough to eliminate toxicity without causing deficiencies (Sanchez, 1977). Spain et al. (1975) studied the effect of 0, 150, 1,000, 2,000, and 4,000 kg/ha of CaCO_3 on the yields of 'La Libertad' stylo, centro, puero (Pueraria phaseoloides (Roxb.) Benth.), and Greenleaf desmodium. In the first harvest the highest dry-matter yields were obtained at the 150 kg/ha of lime for all legumes. The authors stated that it seemed that lime was required basically as a source of Ca and/or of Mg by the legumes. The authors also pointed out that several research experiments in the literature are based on the use of 1 ton of lime as the first level. Consequently, these investigations never measure the response potential of some species to smaller lime applications, especially in Oxisols. The authors also emphasized the importance of Ca and Mg as soil nutrients, mainly in soils where high exchangeable Al levels and low exchangeable Ca and Mg levels occur.

Phosphorus, Sulfur, Potassium, and Micronutrients

Phosphorus deficiency in acid tropical soils usually occurs together with Al toxicity. Poor legume growth in Oxisols and Ultisols has often been attributed to the low levels of available P. The P-fixing capacities of these soils increase as the contents of Fe and Al oxides increase. Also, the higher the exchangeable Al content, the larger the P-fixing capacity. For adequate plant uptake and use, H_2PO_4^- ions in the soil solution should be between 0.07 to 0.2 ppm according to Sanchez (1977).

Tropical legumes vary in their tolerance to low available P. Fox et al. (1974) reported that it is necessary to apply P during the establishment phase of most tropical legumes. The authors determined that Desmodium aparines DC. required 0.20 ppm of P in the soil solution to give 95% of its maximum yield (critical level) during the establishment phase, while requiring only 0.01 ppm P in the solution after the second cutting. Andrew and Robins (1969) in Australia determined the critical P concentrations in the tops of several tropical legumes. They considered the percent P in the tops associated with maximum plant growth as being the critical levels. Critical levels were 0.17, 0.16, 0.22, 0.23, and 0.25% for Townsville stylo, centro, Greenleaf desmodium, glycine, and alfalfa, respectively. The physiological mechanisms responsible for these varietal and species differences are not fully understood. Salinas and Sanchez (1976) in reviewing the subject, reported that species more tolerant to low available soil P either absorb P at a faster rate or are able to translocate it to the tops more rapidly than do species not tolerant to low P availability.

In Florida, Snyder and Kretschmer (1974) obtained small linear increases in dry-matter yields of Siratro, Cook stylo, carpon desmodium

(Desmodium heterocarpon (Linn.) DC.) and centro when lime was applied in 500 kg/ha increments up to 3,000 kg/ha without P fertilization. When the same levels of lime were used together with 45 kg/ha of P, the response to lime was linear through the 2,000 kg/ha and curvilinear thereafter.

Since Oxisols and Ultisols have high P-fixing capacities, applying less soluble sources of P, such as rock phosphate, may be more economical and effective than the highly soluble forms. Rock phosphate is more reactive in acid soils and usually costs from a third to a fifth as much as superphosphate per unit of P (Sanchez, 1977). In addition, another strategy recommended is the addition of lime or silicate, the later being able to react with some of the P-fixing sites in the soil. According to Sanchez (1977) liming soils to pH 5.5 generally increases the availability of P and precipitates the exchangeable Al and some hydroxy Al as Al hydroxides, which fix less P. Mendez-Lay (1973) in Panama found that on an Oxisol limed to pH 5.5, 80% of the maximum dry-matter production of millet (Pennisetum americanum (L.) K. Schum) was obtained when soil pH was raised to 5.5 and 115 ppm of P were added. At pH 4.8 twice as much P was needed to produce the same yield. Fox et al. (1964), in Hawaii, reported large increases in P uptake by several pasture species, once soils which had high P-fixing capacities, were limed to pH 5.0 and 6.0. They also reported that at pH values above 6.0, P uptake was decreased, attributing the effect to the formation of insoluble forms of calcium phosphate.

Soil microbiologists are becoming increasingly optimistic with the possibility of exploring the already proven potential of vesicular-arbuscular Mycorrhiza inoculation of tropical legumes. Mosse

(1977) reported that the utilization of added rock phosphate by stylo was considerably increased by inoculation with Mycorrhiza. An important secondary effect of inoculation with Mycorrhiza in P deficient soils is the stimulation of nodulation and symbiotic N-fixation by Rhizobium spp. The possibility of naturally occurring Mycorrhiza-tropical legume associations is sometimes speculated as being the reason that some tropical legumes like Stylosanthes spp. have higher P extraction capacities.

After N and P, S is considered by many as the next most important major element required for tropical legume growth. Sulphur-deficient legumes retain much of the N absorbed or fixed in the roots, not translocating it to the tops (Jones and Robinson, 1970). They also mentioned that small applications of S satisfy the S requirements of legumes such as Townsville stylo, permitting upward N translocation. The author reported maximum top yields of Townsville stylo with the addition of 4.5 kg/ha of S, while N content of the tops increased up to a maximum with 12 kg of S. Tergas (1977) reported the significance of S on the growth and nodulation of several different tropical forage legumes. Centro and Dolichos sp. did not respond to S applications on a soil low in sulphur. However, Siratro and centro dry-matter and nodule weight increased as S applications were increased. Sanchez (1977) pointed out that S deficiencies are widespread throughout the tropics, and that some pasture legumes are more susceptible to S deficiency than other crops; but that the rates of S needed to correct deficiencies can be supplied by ordinary superphosphate or by ammonium sulphate applications.

Potassium (K) has been less studied than some of the other major elements, even though it is an element that can be deficient in many of the tropical soils. Heavily weathered, sandy and well-drained soils are usually deficient in K. Norris (1972) pointed out the importance of K on maintenance of legumes in legume-grass mixtures, since at low soil K levels, extraction capacity of legumes is lower than that of grasses. Jones (1966) reported that an application of 90 kg/ha of K increased the Siratro component of a Siratro-setaria sward from 2 to 20%. In an experiment designed to study the competitive ability for K of Siratro and setaria, Whelan and Edwards (1975) observed that at high and low K levels, setaria absorbed considerably greater K than Siratro. Hall (1974) had already shown that at a low level of K, setaria severely restricted the growth of Greenleaf desmodium. When high levels of K fertilizer were used in the mixed sward, setaria dry-matter yields were increased without detriment to the yield of the legume component. Greater K extraction capacity of the grass component could restrict legume growth and persistence in the mixture, if K in the soil is low. Disappearance of the legume for this or other causes would then result in grass growth limitation through development of a secondary N deficiency. Restoration of the productivity of such a depleted pasture would rely, not only on the application of K but also on the re-establishment of the legume component in the pasture. Therefore, the maintenance of well-balanced grass-legume mixtures may be affected by soil K status.

Micronutrients can play an important role in tropical legume growth, mainly because of their function in several enzyme systems and in N fixation by Rhizobium-legume associations. In Australia,

molybdenum (Mo) has been recognized as essential for legume growth and molybdenized simple superphosphate is used for establishment and maintenance of tropical legume pastures (Moore, 1970). Molybdenum is an essential metal for enzymes involved in N fixation and nitrate reduction (Epstein, 1972).

De-Poli and Döbereiner (1974) in Brazil studied the effect of micronutrients on the establishment of centro, Siratro, and stylo. Soil applications of FTE BR-10 doubled the protein production of all legumes tested but when it was used for seed pelleting only centro and Siratro benefited. Applications of FTE BR-10 by itself in pellets induced chlorosis on the legume seedlings. The chlorosis was almost completely eliminated by adding lime with FTE or by layering the pellets with FTE and lime. In culture medium, *Rhizobium* was not inhibited by any of the FTE formulations studied.

Rodriguez-Gomez and Blue (1974) in Florida conducted a greenhouse study to determine the effects of lime and FTE on growth and chemical composition of several tropical grasses. The authors used as growing substrate the top 15 cm of virgin Leon fine sand soil. Pangola and bahiagrass responded to micronutrient applications at all lime levels. Maximum bahiagrass growth occurred with an application of 0.5 ppm Cu. Critical forage Cu concentration for bahiagrass was about 2.5 ppm. They concluded that, if acid sandy soils are limed to pH values above 5.5, the probability of micronutrient deficiencies would increase and that care should be exercised to insure adequate quantities. Sanchez (1977) pointed out that in the tropical Oxisols and Ultisols, liming at rates higher than those needed to neutralize the exchangeable Al or eliminate Mn toxicity will cause soil structure deterioration, and

decreased availability of P, B, Zn, and Mn. Zinc deficiencies have been reported for Cerrado Oxisols in Brazil (North Carolina State University, 1973) when liming these soils to pH 6 to 7.

Vargas and Döbereiner (1974) in Brazil, in greenhouse studies, showed that stylo nodulation and dry-matter yields were reduced by half when soil was limed to pH 6.8. When B and Mn were added, however, significant growth responses were obtained.

Werner et al. (1975) studied tropical legume response to the micro-nutrients Mo, Cu, Zn, B, Fe, Mn, and Co in the form of FTE BR-10 and in the salt form. Using three tropical legumes cultivated in pots, they observed visual symptoms of Mn toxicity on glycine and B toxicity on stylo. This work emphasizes that there is a narrow range between deficient and toxic levels of some micronutrients.

Persistence of Tropical Legumes Growing in Mixture With Tropical Grasses

The advantages of having a legume-grass association as a pasture system for the tropics have already been emphasized in previous sections of this literature review. The maintenance of this type of system, in many instances, has been difficult to achieve.

All factors mentioned as affecting establishment, also will affect the persistence of the legumes in the mixture. The following factors are usually considered to be the most important ones in determining persistence of legumes growing in association with grasses: (a) environmental factors such as light, temperature, and soil moisture; (b) growth habits of the components of the mixture; (c) efficient nodulation of the legumes; (d) edaphic factors such as soil pH and nutrient supply; (e) frequency and height of defoliation; (f) grazing

intensity and relative palatability of the components of the mixture; (g) seed production capacity particularly for annual legumes; (h) ability to survive drought and cold particularly for perennial legume species; (i) pests and diseases.

Light, Temperature, and Moisture

Most tropical grass species are C_4 plants and having a unique CO_2 fixation pathway, which at high light intensities and temperatures, confers higher photosynthetic rates to these species than to tropical legumes, which are C_3 plants (Leopold and Kriedeman, 1975; Wilson and Ludlow, 1970). According to Ludlow and Wilson (1970), tropical grasses achieve two to three times higher photosynthetic rates than tropical legumes. This condition gives an ecological advantage to C_4 -grass species permitting them to dominate and even exclude the C_3 -legume component from the mixture. The same authors, however, point out that if environmental conditions characterized by lower light and temperatures than those required by the C_4 grasses prevail, C_3 legume species would be favored and could become more competitive.

Tow (1967) working in controlled environmental conditions compared growth rates of glycine and Green panic guineagrass at different light intensities and root temperatures. Results showed that Green panic had higher dry-matter yields than glycine at all light intensities. Higher dry-matter yields were also reported for Green panic at the higher root temperatures. Although temperatures above $30^\circ C$ caused a reduction in growth in both species, Green panic was less affected than glycine. These and other results have indicated that tropical grasses have a competitive advantage over tropical legumes when

growing in a mixture, especially when light intensity and high temperatures exist. This competitive ability, however, depends in large part on growth habits of the associated species.

There is very little information on the response of tropical pasture species to shading. Practical applications of shading responses mainly of the legume component of the mixture, are of great significance and can help to explain and compare the behavior of grass-legume associations in pasture conditions. Tang (1976) in a greenhouse study, showed that under full sunlight 90 cm high joint vetch plants which were cut below the second node yielded significantly more dry-matter than plants cut at the same height and stage but grown under partial shade. The author also observed that joint vetch plants cut below the second node level when 45 cm tall and under partially shaded conditions, died after the first harvest. Ludlow et al. (1974) compared growth responses of grasses and legumes to shading in the absence of inter-plant competition for light. At early stages of growth, leaf area and dry weight of all species were depressed by shading, the effect on dry weight reduction being especially marked in Green panic. Legumes had higher leaf area ratios at all levels of illuminance, showing a more accentuated increase as illuminance decreased than did the grasses. The last observation seems to be a general rule, since similar behavior has been reported when glycine and Green panic (Tow, 1967), and Phaseolus vulgaris L. and corn (Zea mays L.) leaf area ratios (Rajan et al., 1973) were compared at different shading regimes. Shading always had a greater effect on the growth characteristics of grasses than on legumes, tending to reduce the inherent differences between them, so that in shaded situations similar photosynthetic capacities

were achieved by both. Ludlow et al. (1974) pointed out that since growth rate and size are determinants of competitive ability, neither grass or legume would appear to have an advantage at seedling stage if both were seeded into a taller pasture canopy.

Growth habit and leaf geometry of the species that compose the mixture are important characteristics influencing light interception and consequently their compatibility, persistence and production. Santhirasegaram (1975) in the humid tropics, reported that if well-managed, pasture mixtures of guineagrass and centro can be maintained. It was suggested that the reason for the legume persistence was its viney growth habit, enabling it to climb the stems of the tall growing grass, thus intercepting sufficient radiation. Santhirasegaram et al. (1966), however, made the remark that while twining legumes may have the advantage of placing more leaves in regions of high light intensity, this creates the risk that too many dormant buds are grazed, restricting the number needed for regrowth and persistence. They suggested that the ideal type of twining legume should have a stoloniferous or rhizomatous growth habit in order to withstand frequent defoliation under grazing conditions.

Most tropical legumes are phototropic, orienting their leaves to intercept maximum light intensity. This effect, however, is modified by water stress as shown by Begg and Torssell (1974). Under fully turgid conditions, leaflets of Townsville stylo are oriented at right angles to the direction of the incident radiation (diaphotonasty) and the leaflets follow the course of the sun in this position, thus maximizing light interception. Under conditions of severe water stress, however, leaflets orient themselves parallel to the incident radiation

(parahelionasty) thus minimizing the interception of radiation. A parahelionastic response in the field, according to the authors, increases the growth rate and chances of persistence of establishing seedlings. Fisher and Campbell (1977) confirmed these results with Townsville stylo in Katherine, Australia, which has about 500 mm annual rainfall. Swards subjected to simulated drought behaved in a similar fashion regardless of growth stage. When minor drought stress was imposed upon the swards, plants remained turgid throughout the day, with the diaphotonasty effect predominating. As drought stress was increased, however, the parahelionasty effect predominated, reducing the amount of leaf surface exposed to the sun. Tothill and Jones (1977) reported similar characteristics for Siratro. These are very important mechanisms for survival of annual and perennial tropical legumes particularly when legumes are partially shaded by the associated grass.

If all other growth factors are adequate, amount and distribution of rainfall are the most important factors determining pasture productivity. Burton et al. (1957) discussed aspects of water availability in relation to soils, evaporation, and forage growth. They pointed out that even with well distributed rainfall during the warm growing season in the Southeastern United States, the low water-holding capacity of the sandy soils which predominate in the area, and the high water-use requirements associated with the high summer temperatures caused dry spells to be more damaging than similar rainfall deficits on finer textured soils.

Rainfall patterns in the tropics are very diverse, ranging from desert conditions to areas with more than 4,000 mm of annual

precipitation. Many areas are similar to those in Queensland, Australia, and Central Brazil, with wet-dry climates. These climates are characterized by varying lengths of the dry season lasting from 3 to 8 months. There are also climates like those of south Florida, where flooding conditions can occur during the summer period. Persistence of tropical legumes under either extreme condition can be a problem. In south Florida, much of the land available for pasture production may be waterlogged for several days or weeks during the summer. This situation can contribute to lack of persistence of legumes which are not resistant to flooding conditions. Besides the effect of flooding, Kretschmer (1978) stated that temperature, soil oxygen levels, uptake of toxic elements, and plant age can be contributing factors. It was also pointed out that seedlings are less resistant to flooding than mature plants. Kretschmer (1978) also stated that there are species differences, joint vetch and phasey bean being better adapted to flooded conditions than Siratro.

Diseases, Insects, and Nematodes

A wide array of insects, nematodes, and diseases can attack and in many instances severely damage tropical legume plants. The degree of damage depends on legume species and on prevailing environment.

The increasing interest on the use of tropical legumes has given rise to intensive plant introduction and collection programs in many tropical countries. When plants are introduced from other areas, they are not always free of diseases, and seed-borne diseases may be introduced inadvertently. Sonoda (1975) pointed out that introduced plants may become infected by diseases not reported from their area of origin. On the other hand, the pathogen may be endemic to the new area, and not have been recognized in the area of the plant's origin.

Anthrachnose (Colletotrichum sp.) is the most severe disease attacking Stylosanthes spp.. The disease was first recorded in 1937 in Brazil (Sonoda, 1975). The pathogen had not been observed in Florida until 1971, when it was first reported. It is assumed that it was introduced into Florida on Stylosanthes spp. seed (Sonoda, 1975). The commercial varieties of Stylosanthes originating from Australia have shown to be highly susceptible to Anthracnose when grown in Latin America (CIAT, 1976).

In Colombia, Ellis et al. (1976) reported the occurrence of Colletotrichum gloeosporioides on surface sterilized pods and seeds of Stylosanthes spp. The pathogen has been reported to reduce yields of some of the Stylosanthes spp. accessions in Colombia (Baudion et al., 1975) and is now regarded as being seed transmitted (Lenne and Sonoda, 1978). From the 600 Stylosanthes accessions tested for Anthracnose tolerance in Colombia, approximately 8% showed a high degree of tolerance to the disease. Among the accessions found to be resistant were several ecotypes of Stylosanthes capitata Vog., a perennial species native to eastern Brazil and Venezuela. These ecotypes also showed resistance to stemborer (*Zarathra* sp.) which can drastically reduce yield of susceptible species (CIAT, Annual Report, 1976).

In Florida, Lenne and Sonoda (1978) reported that Rhizopus stolonifer was the most common fungus associated with seeds of Verano stylo harvested at the Agricultural Research Center, Fort Pierce. They suggested that seed-borne fungi may affect Stylosanthes spp. seed emergence and seedling survival in field conditions.

Another disease that often attacks tropical legumes is web-blight (Rhizoctonia solani) which has been reported to occur on Siratro

in Florida (Sonoda et al. 1971). The disease appeared to be especially severe where the growth was dense. Clipping appeared to retard it. In Brazil, Siratro has also shown to be susceptible to Synchytrium spp. (Namerata et al., 1974) especially in seed production fields where microenvironmental conditions were favorable for fungal growth. The pathogen has not been reported to affect Siratro growing in mixture with grasses, nor has it been reported elsewhere in the tropics. Siratro is resistant to root-knot nematodes and to little-leaf virus which may attack various other tropical legumes (Bogdan, 1977).

A survey done in north coastal New South Wales, Australia, assessed the importance of insects on some of the tropical legumes (Braithwaite and Rand, 1970). The most important pests recorded were the native weevils belonging to the species Amnemus quadrituberculatus and A. superciliaris, which attack the roots and foliage of Desmodium spp. and glycine. The most serious damage by these insects occurred by larvae attacking the roots. In case of high infestation a severe stress is imposed upon the plants in late autumn and winter on the semi-dormant plants, which either die or have their growth severely retarded in the following spring. In a mixed grass-tropical legume pasture, the effects of feeding by Amnemus larvae may be so severe that the pasture becomes grass dominant. Siratro and Vigna spp. resist attacks by these insects.

In south Florida, Kretschmer (1978) reported that the bean leaf roller caterpillar (Urbanus protus L.) damaged leaves of Centrosema spp. The damage, however, was not permanent, and plants recuperated.

Nematodes have shown to be the causes of drastic reduction in stands of some of the tropical legumes. Kretschmer (1978) reported

that carpon desmodium is highly susceptible to root-knot nematode (Meloidogyne incognita). Winchester and Hayslip (1960) reported that the root-knot nematode population declined in the presence of Pangola digitgrass while increasing rapidly in the presence of white clover, carpetgrass, and Pensacola bahiagrass. Winchester (1960) found that water extracts of Pangola roots reduced or eliminated the cotton root-knot nematode in cucumbers compared with distilled water check plants.

Sonoda (1975) pointed out that the most economical means for control of plant diseases, especially for forage plants is through incorporation and maintenance of genes for resistance or tolerance in plants. In a previous paper by the same author (Sonoda, 1973), all lines selected from Townsville stylo IRFL #850 on the basis of better agronomic characteristics, were reported to be more severely affected by Anthracnose than the original plant material. These results emphasize the importance of pest and disease resistance as a selection characteristic to be considered in evaluation or breeding programs.

MATERIALS AND METHODS

General Description of the Experimental Area

The two field experiments that constitute the present research work were conducted at the Agricultural Research Center of Fort Pierce (ARCFP), Florida, a part of the Institute of Food and Agricultural Sciences (IFAS), University of Florida.

The ARCFP is located at 27°27' N latitude and 80°25' W longitude, and the climate of the area according to the Thornthwaite's Classification is a Cb'r (Mesothermal Sub-humid climate, with rainfall adequate in all seasons) type. Weather records taken at the ARC weather station representing an average of 25 years show a mean annual precipitation of 1433 mm, with 65% falling from 1 June to 1 November.

As a consequence of this rainfall pattern, frequent and short to lasting floodings in the summer and severe droughts in the spring may occur in pasture areas. Temperatures below 1° C and consequently frosts are more likely to occur in December, January, and February which are the coldest month. Number of hours with temperatures below 1° C representing an average of 25 years were 62, 114, and 41 for the December, January, and February months, respectively (A. E. Kretschmer, Jr., unpublished data). The monthly temperatures and rainfall data recorded at the ARCFP from July 1976 through June 1978 are presented in Tables 1 and 2.

Table 1. Monthly mean maximum and minimum temperature and rainfall at the Agricultural Research Center, Fort Pierce for the 1 July 1976 - 31 June 1977 period.

Month	Temperature				Rainfall	
	1976-77		1959-69		1976-77	1952-76
	Max	Min	Max	Min		
	----- ° C -----				----- mm -----	
July	32.2	20.8	32	22	60	186
August	31.9	21.9	33	23	133	172
September	30.8	20.5	32	22	122	191
October	28.2	17.1	29	19	9	186
November	24.8	13.7	27	16	72	55
December	22.2	11.7	24	12	51	46
January	19.8	5.8	23	10	34	53
February	22.7	9.0	25	12	49	79
March	27.0	15.0	26	13	13	81
April	27.6	14.9	28	16	14	65
May	28.8	17.3	30	19	81	127
June	32.4	20.2	32	21	86	193

Table 2. Monthly mean maximum and minimum temperatures and rainfall at the Agricultural Research Center, Fort Pierce for the 1 July 1977 - 31 June 1978 period.

Month	Temperature				Rainfall	
	1977-78		1959-69		1977-78	1952-76
	Max	Min	Max	Min		
	----- ° C -----				----- mm -----	
July	32.1	20.8	32	22	173	186
August	31.7	22.5	33	23	157	172
September	32.2	22.5	32	22	309	191
October	28.5	17.5	29	19	94	186
November	26.6	15.5	27	16	86	55
December	24.0	12.0	24	12	95	46
January	20.5	8.3	23	10	69	53
February	20.0	7.6	25	12	63	79
March	24.7	13.1	26	13	81	81
April	27.8	14.4	28	16	44	65
May	30.3	19.0	30	19	180	127
June	30.4	19.5	32	21	227	193

The soil of the experimental area is an Oldsmar fs a member of the sandy, siliceous, hyperthermic family of Alfic Arenic Haplaquods of the Spodosol order (Caldwell, 1978) which is poorly drained and has an organic hardpan layer about 1 m below the surface.

Development of the Experimental Site

The areas used in the present research were 3-year-old sods of Pangola and Bigalta. Results of soil analyses from samples taken in early summer of 1976, prior to the establishment of the experiments showed: pH (H_2O) = 6.3; Ca:Mg ratio 8.5:1; P = 6.1 ppm; and K = 4 ppm for the Pangola area, and pH = 6.3; Ca:Mg ratio = 7.6:1; P = 6.1 ppm; K = 2 ppm for the Bigalta field. Calcium, Mg, P, and K are extractable (1N NH_4 OAc, pH 4.8) values. Due to the relatively high pH values and adequate amounts of extractable Ca, Mg, and P levels revealed by the analyses, no lime or P-fertilizer were used at seeding time. However, due to the low extractable soil K levels, 42 kg/ha of K were applied (as 60% muriate of potash) 5 weeks after seeding. In addition to the K-fertilizer, 25 kg/ha of FTE 503^{1/} were applied 8 weeks after seeding. Soil pH (H_2O), extractable (double acid, 1:4 dilution factor) Ca, Mg, P, K, Cu, Fe, Zn, Mo, and Na values were determined on soil samples taken in the springs of 1977 and 1978. These analytical results, (Appendix Table 1) indicated no further need for micronutrient fertilization. On 3 December 1976, 35 kg/ha of K and 25 kg/ha of P, and on 29 June 1977, 80 kg/ha of K and 58 kg/ha of P were used (as a 0-10-20 commercial fertilizer), while on 10 June 1978, 83 kg/ha of K (as muriate of potash) was applied to each area.

^{1/} FTE 503 contains 18.0% Fe, 7.5% Mn, 7.0% Zn, 3.0% Cu, 3% B, and 0.2% Mo.

Treatments and Experimental Design

The treatments compared in the present study were:

A. Main plots - seedbed preparation methods:

1. NT - no tillage, seed broadcast
2. DS - light discing, seed broadcast, cultipacked
3. SD - seed broadcast, light discing, cultipacked
4. SS - sod-seeding
5. CSP - complete seedbed preparation, seed broadcast, cultipacked

B. Subplots - legume species:

1. 'Siratro' (Macroptilium atropurpureum (DC.) Urb.).
2. Centro (Centrosema pubescens Benth.)
3. Joint vetch (Aeschynomene americana L.)
4. 'Verano' Caribbean stylo (Stylosanthes hamata Taub.)
5. 'Florida' carpon desmodium (Desmodium heterocarpon (L.) DC.).

The treatments were arranged in a split-plot design with five replications.

Experimental Procedures

The experimental areas were mowed to a 5-cm height 3 days prior to treatments being applied. The Bigalta and Pangola fields were seeded on 21 July and 23 July 1976, respectively. Legume seeds were inoculated with Rhizobium spp. (wide spectrum inoculant, type EL, Nitragin Company, Milwaukee, Wisconsin) and seeded to provide an estimated 110 viable seeds per m². Complete seedbed preparation consisted of discing and rototilling to a depth of 15 cm until a clean cultivated appearance was obtained. For the discing treatments, one pass by a

light disc with the tractor in low gear was used to cut grass stolons and penetrate the soil to a maximum depth of 2 cm. For the sod-seeding treatment, a 'Zip-seeder' machine was used. With this machine, seeds were planted into the sods about 2 cm deep in six rows 23 cm apart. Main plots were 10 m long and 2 m wide, and 2 by 2-m subplots were separated by 2-m alleyways.

Observations and Measurements Taken

Establishment Phase

In order to assess the effects of seedbed preparation treatments on the establishment of the legumes, seedling counts and dry-matter yields were taken up to the first 4 months after seeding. Seedling counts were made with the aid of a wooden frame 3 and 6 weeks after seeding.

The wooden frame used as an aid in counting the seedlings consisted of two rows of three sections each. Attached to each of the outer corners of the frame was an iron foot with a hole (Fig. 1). These holes were fitted onto four permanent rods, placed in the field plots. After the frame was affixed to the permanent rods in each plot, a clear polyethylene plastic sheet was attached. A felt-tipped pen was used to mark the plastic directly above the seedlings (Fig. 2). By using the same plastic sheets and felt pens with different colors, new and persisting seedlings were recorded.

Soil temperatures were taken at the surface and at a depth of 2.5 cm with the aid of a thermistor thermometer. These data were taken on complete seedbed preparation and on the disced plots during the first 2 weeks following

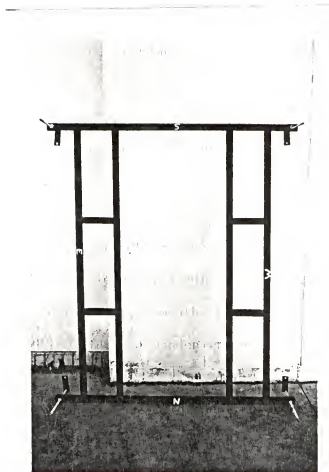


Fig. 1. Wooden frame used for seedling counts (Notice height adjustable legs on corners of frame).

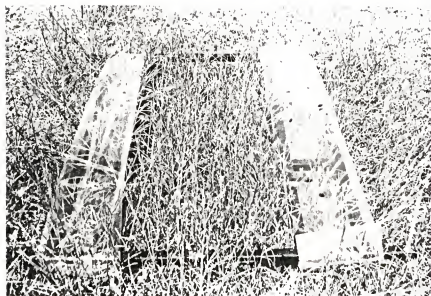


Fig. 2. Wooden frame, with attached plastic sheet, positioned in a field plot. (Notice felt tip pen marks where seedlings were found).

seeding. Moisture content of the 2.5-cm surface of the soil was also recorded at several occasions for the same plots. To characterize the temperature requirements for germination of the different legume species used, a study under controlled environmental conditions was undertaken. Fifty seeds each of 10 different tropical legumes were germinated on filter paper in Petri dishes placed in incubators set at 30, 38, and 46° C for 8 hours alternated with 25° C for 16 hours. These treatments were chosen because field data had shown that these temperatures were within the range that normally occurs at the soil surface during the summer time depending on rainfall and vegetation coverage (Appendix Tables 3 and 4).

Dry-matter yields were determined by harvesting a 76-cm wide strip in the middle of the plots, using a sickle-bar plot mower that left a 10-cm stubble. Fresh weight yields were recorded in the field and subsamples of about 0.5 to 1.0 kg were taken for botanical separation and dry-matter determination. After the subsamples were hand-separated into grass and legume components they were dried at 65° C for 72 hours in a forced-air oven and then weighed for calculating components and total dry-matter yields.

Data from the first harvest, 18 November 1976, terminated the establishment phase.

Persistence Phase

The persistence of the legumes was determined by two countings of the surviving plants in each subplot treatment and by several harvests taken in 1977 and 1978. The number of plants were recorded

(using the wooden-frame technique previously mentioned) at two different occasions, once on 15 August 1977, and the second time two years after seeding time.

Besides these countings three additional harvests, beginning 20 June were made at intervals of about 6 weeks each during the summer of 1977. Also plots were harvested in late December 1977. In 1978, 2 years after establishment of the experiments, plots were harvested on 6 June, 17 July, and on 21 September.

Chemical Composition

Oven-dried subsamples harvested for dry-matter yield determinations were ground through a 1-mm screen in a Wiley mill and submitted to the forage evaluation laboratory for determinations of percent in vitro Organic Matter Digestibility (IVOMD) and Crude protein content (CP). Crude protein content was determined by the Kjeldahl method, according to the procedure recommended by A.O.A.C. (1960) and IVOMD was determined using the Tilley and Terry (1963) method as modified by Moore and Mott (1974). Percent N was multiplied by 6.25 to give CP content. Crude protein yields and Digestible Organic Matter (DOM) were also calculated. Digestible organic matter (DOM) was determined by multiplying IVOMD % x OM % (Organic Matter percentage) x DM % (Dry-Matter percentage) x Yields/ha.

Statistical Analyses

Oven-dry forage yields, chemical composition, and seedling count data were analyzed by the Statistical Analysis System (SAS) designed by Barr et al. (1976) of North Carolina State University. Analyses of variance of dry-matter yields and seedling count data were run as a split-plot design. Data on chemical composition were run as a completely

randomized-design. Duncan's Multiple Range Test was used to determine significant ($P < 0.05$) differences between all mean comparisons made.

RESULTS AND DISCUSSION

Results are presented and discussed separately for the Pangola digitgrass and Bigalta limpogross experiments. Each experiment will be discussed with respect to the establishment and persistence phase. For the sake of brevity the following acronyms for seedbed preparation methods will be used: NT = no tillage; DS = light discing, seeding, cultipacking; SD = seeding; light discing, cultipacking; SS = sod-seeding; CSP = complete seedbed preparation, seeding, cultipacking. Additional acronyms used throughout the text are: DMY = dry-matter yield, CP% = crude protein %, CPY = crude protein yield, IVOMD = in vitro digestible organic matter %, and DOM = digestible organic matter yield.

Pangola Digitgrass Experiment

Year of Establishment (1976)

Number of legume seedlings established.

In Table 3 the number of seedlings (out of 110 viable seeds planted per m²) that germinated and survived 6 weeks after seeding are presented. Generally, more seedlings established in the SS treatment, except for joint vetch, where seedbed preparation methods had no effect on seedling numbers. A significantly lower number of Siratro, centro, and carpon desmodium seedlings established in the CSP treatment. Differences in establishment might have been expected since temperature and moisture availability varied with the degree and type of seedbed preparation used (Hyder and Seneva, 1956; Norman, 1960) and legumes differ with

Table 3. Effect of seedbed preparation and legume species on the number of legume seedlings found in the Pangola sod 6 weeks after seeding (5 to 10 Sept. 1976).

Legume species	Seedbed preparation methods				
	NT	DS	SD	SS	CSP
	----- Number of legume seedlings per m ² -----				
Siratro	46 cdef*	59 bcd	46 cdef	73 b	12 g
Centro	35 defg	52 bcde	43 cdef	64 bc	9 g
Joint vetch	36 cdefg	42 cdef	45 cdef	28 efg	48 bcdef
Verano	42 cdef	26 efg	40 cdef	103 a	29 efg
Carpon	19 fg	29 efg	21 fg	42 cdef	9 g

* Means followed by the same letter are not different at the 0.05 level of significance, according to the Duncan's Multiple Range Test.

respect to temperature requirements for germination (Ruelke et al., 1975; Brolman, 1975). The lower germination observed with Siratro, centro, and carpon desmodium in the CSP treatment is attributed to excessively high temperatures and quicker desiccation of the top 2 cm of soil in this treatment compared with others. Soil temperatures were lower than in the CSP treatment plots (Appendix Tables 2 and 3). The overall average of daily maximum and minimum soil temperatures over a period of 14 days was 38° C for the CSP and 32° C for the DS treatment. A laboratory seed germination test showed that temperatures of 38° C and above substantially reduced germination rates of Siratro, centro, carpon desmodium, and Verano stylo but increased germination rates of joint vetch (Table 4).

Dry-matter yields (DMY) in the first harvest (18 Nov. 1976).

Appendix Table 4 shows the analysis of variance for the DMY data obtained in the first harvest. Tables 5, 6, and 7 show the DMY of the Pangola-legume components as well as the percentage legume in the mixtures as affected by seedbed preparation and legume species.

The lowest DMY of the Pangola component, and of Pangola-legume mixtures was obtained in the CSP treatment. This was expected since Pangola growth was retarded by the intense soil disturbance.

The legume DMY and legume percentage in the mixtures were low in all treatments at this harvest (Tables 6 and 7). These results showed that productionwise the legumes did not make marked contributions to the DMY of the Pangola-legume mixtures. The results also suggested that when seeding tropical legumes into tropical grass pastures, as late as in the present study (23 July), not much legume component DMY

Table 4. Effect of temperature regimes on seed germination rate after two and five wetting cycles.[†]

Legumes	Temperature (° C)		
	30	38	46
----- Germination rates [‡] -----			
<u>Two wetting cycles</u>			
Siratro	51.4(0.80) a*	35.4(0.63) b	2.0(0.11) c
Joint vetch	15.5(0.40) c	31.0(0.59) b	53.0(0.81) a
Centro	54.0(0.82) a	46.0(0.74) a	27.5(0.55) b
Verano	53.0(0.81) a	38.0(0.66) b	5.0(0.21) c
Carpon	27.0(0.54) a	12.0(0.33) b	2.6(0.15) c
<u>Five wetting cycles</u>			
Siratro	52.5(0.81) a*	39.5(0.67) b	2.0(0.11) c
Joint vetch	18.0(0.43) c	40.5(0.69) b	63.0(0.92) a
Centro	54.0(0.82) a	46.0(0.74) a	27.5(0.55) b
Verano	59.0(0.87) a	43.0(0.71) b	16.5(0.41) c
Carpon	28.5(0.56) a	13.0(0.35) b	4.5(0.21) c

* Means in the rows followed by the same letter are not different at the 0.05 level of significance, according to Duncan's Multiple Range Test.

[†] Each wetting cycle was 5 days long.

[‡] Numbers outside parenthesis are mean germination percentages and numbers inside parenthesis are arcsine transformed values.

Table 5. Effect of seedbed preparation methods on the DMY of the Pangola and legume components and of the Pangola-legume mixtures in the first harvest (18 Nov. 1976).

Plant components	Seedbed preparation methods				
	NT	DS	SD	SS	CSP
	----- kg/ha -----				
Pangola	1695 a*	1672 a	1567 a	1649 a	188 b
Legumes	35 b	62 b	45 b	104 a	32 b
Pangola-legume mixtures	1730 a	1734 a	1612 a	1753 a	220 b

* Means within rows followed by the same letter are not different at the 0.05 level of significance, according to Duncan's Multiple Range Test.

Table 6. Effect of legume species on the DMY of the legume component in the first harvest (18 Nov. 1976).

Plant component	Legume species				
	Siratro	Centro	Joint vetch	Verano	Carpon
	----- kg/ha -----				
Legumes	99 b*	12 c	146 a	19 c	0 c

* Means followed by the same letter are not different at the 0.05 level of significance, according to Duncan's Multiple Range Test.

Table 7. Effect of seedbed preparation methods and legume species on the legume content of the Pangola-legume mixtures in the first harvest (18 Nov. 1976).

Legume species	Seedbed preparation methods				
	NT	DS	SD	SS	CSP
	----- % legume in the mixture -----				
Siratro	4.7 cde	4.1 ced	5.6 cde	15.2 b	18.4 b
Centro	0.2 e	2.3 cde	0.1 e	1.2 de	0.2 e
Joint vetch	4.0 cde	10.6 bcd	7.7 bcde	11.7 bc	27.5 a
Verano	0.8 e	1.4 de	1.5 de	2.3 cde	2.0 cde
Carpon	0.0 e	0.0 e	0.0 e	0.0 e	0.0 e

* Means followed by the same letter are not different at the 0.05 level of significance, according to Duncan's Multiple Range Test.

can be expected in the establishment year. The low DMY of the legumes can be attributed mainly to the Pangola digitgrass competition and to the unfavorable environmental conditions characterized by lower than normal temperature and rainfall which occurred late in the summer and during the fall (Table 1).

Effect of legumes on DMY, CP%, CPY, IVOMD, and DOM

There were no significant differences in the Pangola component DMY, CP%, or DOM, regardless of the legume content in the mixture (Table 8). The slight differences for IVOMD are unexplainable and of little practical significance. Data for legume component CP%, although significant, also are of little practical consequence because all were adequate for animal requirements. At harvest, joint vetch had produced seeds and contained few green leaves which explains its lower CP%. This condition is also reflected by the IVOMD content of about 49% compared with greater than 60% for Siratro and Verano. Contribution to total dry-matter of 10% Siratro and joint vetch were equal and better than 5% of Siratro and Verano in the mixtures. These DMY differences are responsible for the differences in CPY and DOM.

Although few significant differences are shown for legume-grass mixtures, it is important to note that CP% of all mixtures was very low and not adequate (7% and below) to maintain maximum forage intake by cattle.

Overall results indicated that DMY and CP% of grass-legume mixtures can be very low when the tropical legumes are sown the last week of July. Unpublished data (Kretschmer and Snyder) indicate that yields and CP% will be higher if tropical legumes are established in late May or early June.

Table 8. Forage DMY, CP%, IVOMD, CPY, and DOM data from the first Pangola-legume harvest (18 Nov. 1976).

Legume content in the mixture	Forage yield and quality measurements				
	DMY	CP	IVOMD	CPY	DOM
	kg/ha	%	%	kg/ha	kg/ha
<u>Pangola component</u>					
0% legume	1384 a*	3.5 a	49.7 ab	47.9 a	644 a
5±2% Siratro	1341 a	3.8 a	51.9 a	50.1 a	654 a
10±2% Siratro	1305 a	3.9 a	48.7 b	49.7 a	591 a
10±2% joint vetch	1314 a	3.7 a	47.5 b	49.1 a	586 a
5±2% Verano	1367 a	3.3 a	49.9 ab	46.2 a	643 a
<u>Legume component</u>					
5±2% Siratro	68 b	14.4 a	62.3 b	9.6 ab	39 b
10±2% Siratro	143 a	11.8 ab	61.0 b	16.1 a	79 a
10±2% joint vetch	146 a	10.9 b	48.6 c	15.7 a	67 ab
5±2% Verano	53 b	12.7 ab	69.4 a	6.7 b	34 bc
<u>Pangola-legume mixtures</u>					
0% legume	1384 a	3.5 c	-	47.9 a	644 a
5±2% Siratro	1409 a	4.3 ab	-	59.8 a	694 a
10±2% Siratro	1448 a	4.6 a	-	65.8 a	670 a
10±2% joint vetch	1460 a	4.4 a	-	64.8 a	653 a
5±2% Verano	1420 a	3.7 bc	-	53.0 a	677 a

* Means within each column, within each component, followed by the same letter are not different at 0.05 level of significance, according to Duncan's Multiple Range Test.

Second Year (1977)

Dry-matter yields (DMY)

The DMY of three harvests taken in the summer of 1977 and one taken in the winter of the same year are presented and discussed here.

Second harvest (20 June 1977). The analysis of variance for DMY (Appendix Table 4) revealed a significant ($P < 0.05$) effect of the legumes on the DMY of the legume component in Pangola-legume mixtures and on legume percentage in the mixtures. Siratro component DMY were higher than any other legume. Pangola-Siratro mixtures were responsible for the highest DMY, with the legume composing 42% of the total mixture yield (Table 9). The other legumes yielded little or no forage at this harvest. Low yields of joint vetch resulted from seedlings being only 10 cm high and not from lack of plant numbers. Joint vetch, being an annual, was not damaged by the cold winter temperatures in 1977 (Table 1). Low temperatures, however, severely damaged Verano stylo, carpon desmodium, and centro resulting in slow recuperation of the few surviving plants and low or no yields. Siratro, however, recuperated well from winter, and its early growth in the spring resulted in the highest legume yields in the summer of 1977.

Third harvest (2 Aug. 1977). There were no significant ($P < 0.05$) treatment effects on DMY of the Pangola component (Appendix Table 4). Highest DMY for Pangola-legume mixtures, and legume component as well as the highest percentage legume in the mixtures were obtained with joint vetch in the CSP treatment (Table 10). Siratro-Pangola mixtures and particularly Siratro component DMY were somewhat higher in the

Table 9. Effect of the legume species on DMY of Pangola-legume mixtures, legume component, and legume content of the mixtures in the second harvest (20 June 1977).

Plant components	Legume species			
	Siratro	Centro	Joint vetch	Verano
				Carpon
			kg/ha	
Pangola-legume mixtures	998 a*	577 b	613 b	610 b
Legumes	442 a	1 b	32 b	0 b
			%	
Legumes in mixtures	42.0 a	0.1 b	5.0 b	0.0 b
				3.0 b

* Means followed by the same letter are not different at the 0.05 level of significance, according to Duncan's Multiple Range Test.

Table 10. Effect of seedbed preparation methods and legume species on DMY of the legume component, Pangola-legume mixtures, and on the legume percentage of the mixtures in the third harvest. (2 August 1977).

Legume species	Seedbed preparation methods			
	NT	DS	SD	SS
CSP				
Legume component				
kg/ha				
Siratro	430 c*	392 c	352 c	670 b
Centro	0 e	2 e	1 e	10 e
Joint vetch	33 e	131 e	159 de	155 de
Verano	0 e	0 e	0 e	21 e
Carpon	43 e	114 e	6 e	27 e
Pangola-legume mixtures				
kg/ha				
Siratro	1378 b*	1161 bc	1014 cd	1388 b
Centro	795 de	701 de	734 de	751 de
Joint vetch	875 cde	832 de	790 de	797 de
Verano	743 de	729 de	867 cde	745 de
Carpon	714 de	910 cde	610 e	676 de
Legumes in the mixture (%)				
Siratro	31.4 b	34.8 b	34.2 b	48.7 a
Centro	0.0 f	0.3 f	0.2 f	1.2 f
Joint vetch	3.8 ef	13.6 de	16.5 cde	17.3 cd
Verano	0.0 f	0.0 f	0.0 f	0.0 f
Carpon	5.4 def	9.4 def	1.0 f	2.9 f

* Means followed by the same letter, within each component, are not different at the 0.05 level of significance, according to Duncan's Multiple Range Test.

SS treatment. It can also be noticed that the Siratro component and Siratro-Pangola mixture DMY, and Siratro percentage in the mixtures were quite uniform in all other seedbed preparation treatments. Also the DMY of the legume component and of the Pangola-legume mixtures obtained with other legumes was considerably lower than those obtained with Siratro and joint vetch. The reasons for the superiority of Siratro and joint vetch in the SS and CSP treatments, respectively, can be attributed to the greater number of plants in these seedbed treatments. This is shown by a plant count made 2 weeks after the 1977 harvest (Table 23). The markedly higher DMY obtained with joint vetch in the CSP treatment can be explained by two main factors: first, the higher plant population and second, much earlier germination occurred in this seedbed treatment than in the others due to the higher soil temperatures resulting from the more open sod condition in the CSP treatment. By harvest time, joint vetch plants in the CSP were already fully developed while plants in the other seedbed preparation treatments were still in the seedling stage.

Fourth harvest (20 Sept. 1977). Dry-matter yields of the Pangola component were higher in those treatments in which the grass was growing in association with Verano stylo, carpon desmodium, and centro (Table 11 and Appendix Table 9). Higher DMY of the legume component and of the Pangola-legume mixtures were obtained with joint vetch and Siratro, which composed about 55 and 52%, respectively, of the total mixture DMY. Despite similar percentages, joint vetch yielded almost twice as much forage as Siratro.

Table 11. Effect of the legume species on DMV of Pangola and legume components, of Pangola-legume mixtures, and on legume content of the mixtures in the fourth harvest (20 Sept. 1977).

Plant components	Legume species			
	Siratro	Centro	Joint vetch	Verano
	----- kg/ha -----			
Pangola	540 c	717 b	593 c	823 a
Legumes	654 b	17 c	1010 a	4 c
Pangola-legume mixtures	1194 b	734 c	1603 a	827 c
	----- % -----			
Legumes in mixtures	52.1 a	3.4 b	55.3 a	0.5 b
				4.7 b

* Means within rows followed by the same letter are not different at the 0.05 level of significance, according to Duncan's Multiple Range Test.

Table 12 shows the DMV of each component and of the mixture as affected by seedbed treatments. Dry-matter yield of Pangola, legume, and Pangola-legume components were higher in the CSP than in other treatments. The higher DMV of the legume component average in the CSP treatment are due to the higher yields of joint vetch in this treatment. Joint vetch yielded twice as much in the CSP as in the other seedbed treatments. On the other hand, despite the lower number of plants in the CSP treatment (Table 23), Siratro produced about the same amount of DMV as in other seedbed treatments. The larger DMV of joint vetch in the CSP treatment could have been the cause of the higher DMV of the companion grass, since the amount of N fixed is proportional to dry-matter yields of the legume (Henzell, 1972). Other factors involved could have been less soil compaction (and less waterlogging) and greater soil N mineralization, both of which would stimulate Pangola growth.

Combined summer harvests in 1977. Analysis of variance for total DMV obtained in three summer harvests (20 June, 2 August, and 20 Sept. 1977) is shown in Appendix Table 5. Seedbed preparation methods continued to influence DMV of legumes and consequently Pangola-legume mixtures, although legume species were affected differently. Joint vetch and Siratro component DMV were higher in all seedbed preparation treatments (Table 13), making up, respectively, about 44 and 40% of the total DMV of the mixture (Table 14). Dry-matter yield of the Pangola component was lower when the grass was growing in association with joint vetch and Siratro, the highest yielding legumes (Table 14). These results evidently reflected the effect of legume competition on Pangola yields. Pangola DMV was higher when the grass was growing in

Table 12. Effect of seedbed preparation methods on DMY of the Pangola and legume components and of Pangola-legume mixtures in the fourth harvest (20 Sept. 1977).

Plant components	Seedbed preparation methods				
	NT	DS	SD	SS	CSP
	----- kg/ha -----				
Pangola	647 b*	653 b	668 b	679 b	828 a
Legumes	243 b	374 b	274 b	388 b	448 a
Pangola-legume mixtures	890 b	1028 b	943 b	1067 b	1276 a

* Means within rows followed by the same letter are not different at the 0.05 level of significance, according to Duncan's Multiple Range Test.

Table 13. Effect of the seedbed preparation methods and legume species on combined 20 June, 2 August, and 20 Sept., 1977, DMV of the legume component and of Pangola-legume mixtures.

Legume species	Seedbed preparation methods			
	NT	DS	SD	SS
				CSP
----- kg/ha -----				
Legume component				
Siratro	1425 bc*	1493 bc	1363 bc	2003 b
Centro	9 f	19 f	1 f	72 f
Joint vetch	578 def	1257 cd	936 cd	1154 cd
Verano	0 f	0 f	0 f	0 f
Carpon	88 f	212 ef	56 f	92 f
				1411 bc
				4 f
				2870 a
				21 f
				68 f
----- kg/ha -----				
Pangola-legume mixtures				
Siratro	3528 bc	3187 bcd	3016 cdef	3697 b
Centro	1973 g	1977 g	2005 g	2089 g
Joint vetch	2599 defg	3142 bcd	2603 defg	3045 cde
Verano	2205 g	2057 g	2294 efg	2213 g
Carpon	2329 efg	2352 efg	1994 g	2170 g
				3798 b
				2308 efg
				4990 a
				2259 fg
				2316 efg

* Means followed by the same letter, within components, are not different at the 0.05 level of significance, according to the Duncan's Multiple Range Test.

Table 14. Effect of legumes on combined 20 June, 2 August, and 20 Sept., 1977, DMY of Pangola component and legume percent in mixtures.

Plant components	Legume species			
	Siratro	Centro	Joint vetch	Verano
	----- kg/ha -----			
Pangola	1906 b*	2050 ab	1917 b	2202 a
	----- % -----			
Legumes in mixtures	43.5 a	1.0 c	35.9 b	0.2 c

* Means in the rows followed by the same letter are not different at the 0.05 level of significance, according to Duncan's Multiple Range Test.

association with centro, Verano stylo, and carpon desmodium. These legumes had shown little or no growth throughout the 1977 growing season and consequently did not compete with Pangola.

Winter harvest (21 Dec. 1977). Dry-matter yields of Pangola, legumes, and Pangola-legume components were higher for Siratro and joint vetch, which made up, respectively, about 27 and 28% of the total DMY of the mixtures (Table 15 and Appendix Table 4). It is interesting to note that Pangola yields were larger in December than in the summer when Siratro and joint vetch were present. The competition offered by these legumes was less after the 21 September harvest, allowing better grass growth. In addition, N fixed by the legumes and made available to the grass through mineralization, was believed to have stimulated Pangola growth (Table 15).

Legume effect on Pangola-legume yields in the 1977 growing season

The DMY of Pangola-legume mixtures during the 1977 growing season, 1 year after planting, were greatly affected by legume species. Siratro and joint vetch were the legumes that made the higher contribution to yields. The other legumes made no or very small contribution to the yields of Pangola-legume mixtures in 1977.

It is difficult to isolate the causes of poor survival of centro, carpon desmodium, and Verano stylo from the time of seeding (summer of 1976) until the 1977 growing season. It is known that carpon desmodium is susceptible to long-term flooding and is particularly damaged by root-knot nematodes, which were found in its roots in 1977. Although centro and Verano stylo are resistant to root-knot nematodes, they may not be resistant to ectoparasitic nematodes such as sting, spiral, and others, all of which were detected in the soil in 1977. It is

Table 15. Effect of the legume species on the DMV of Pangola and legume components, of Pangola-legume mixtures and legume percent in the mixtures in the fifth harvest (21 Dec. 1977).

Plant components	Legume species			
	Siratro	Centro	Joint vetch	Verano
	----- kg/ha -----			
Pangola	496 a*	408 b	491 a	408 b
Legumes	198 a	45 b	205 a	1 b
Pangola-legume mixtures	694 a	453 b	696 a	409 b
	----- % -----			
Legumes in mixtures	27.0 a	7.0 b	27.8 a	0.3 c

				1.0 b

* Means within rows followed by the same letter are not different at the 0.05 level of significance, according to Duncan's Multiple Range Test.

doubtful that the high water tables, which were almost continuous during the 1976 summer season, were entirely responsible for differential legume persistence since Siratro which is less tolerant to poor drainage than centro and carpon desmodium maintained high productivity and persistence. Verano stylo seed production was very limited, while centro did not produce any seed in the 1976-1977 period. The low seed production of these legumes was most likely a result of the harvesting schedule and the frosts that occurred during the winter. As a consequence of low seed production, both centro and Verano stylo had very low plant populations and produced little or no growth during the 1977 summer growing season. Siratro and joint vetch were tolerant to these environmental conditions, which resulted in their high productivity in 1977.

The differences in growth pattern and plant population in the year after establishment between Siratro, a moderate seed-producing perennial, and joint vetch, a heavy seed-producing annual, as affected by seedbed-preparation treatments were large. Siratro plants persisted well through the first winter and new seedlings emerged from seed in 1977, providing a stable plant population regardless of seedbed preparation. Joint vetch plant population and consequently seed production in 1976 was greatly increased by CSP compared with other seedbed treatments. This effect was reflected in higher DMY for CSP in 1977. Seedbed preparation was critical for establishment and second year productivity of joint vetch but was less critical for the perennial, Siratro. Furthermore, joint vetch started its productive phase of quality forage about 6 weeks after and ended it about 8 weeks earlier than Siratro. From a duration

of grazing standpoint, Siratro with its relatively long stabilized productivity would be more desirable than joint vetch. From the standpoint of total summer DMY and large DMY production capacity in later summer, however, joint vetch would be more desirable. From the yield standpoint the contribution of both legumes to the total mixture DMY was excellent (Fig. 3). With 40 to 50% legume in the mixture, yields were twice those of Pangola growing alone.

When considering the legume component effect on the DMY of the Pangola component at each of the harvests made during the 1977 growing season, it was observed that except for the 20 September harvest in which Siratro and joint vetch tended to depress the Pangola component DMY, in all other harvests Pangola component DMY were either unaffected or increased (Fig. 3).

Effect of legume on DMY, CP%, IVOMD, CPY, and DOM

Second harvest (20 June 1977). Crude protein and IVOMD of the Pangola component were somewhat higher in mixtures with Siratro and joint vetch than when growing alone (Table 16). Nitrogen fixed by these legumes and made available to Pangola is the most probable explanation for these results. Significant ($P < 0.05$) differences in DMY, CPY, and DOM of the Pangola component were not observed.

When looking at the forage quality and quantity aspects of the legume component, it was shown that joint vetch had better CP% and IVOMD than Siratro, but Siratro provided higher DMY, CPY, and DOM than joint vetch. These results may be better appreciated when Pangola-legume mixture values are compared. The DMY, CP%, IVOMD, and DOM of Pangola-Siratro mixtures were higher than those of Pangola-joint vetch mixtures. These results clearly showed that the Pangola-Siratro

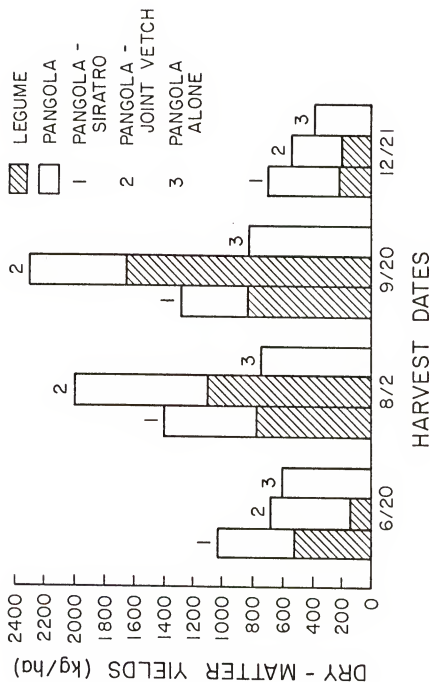


Fig. 3. Effect of legume component on the DMV of the Pangola component and Pangola-legume mixtures during 1977.

Table 16. Forage DMY, CP%, IVOMD, CPY, and DOM data from the second Pangola-legume harvest (20 June 1977).

Legume content in the mixture	Forage yield and quality measurements				
	DMY	CP	IVOMD	CPY	DOM
	kg/ha	%	%	kg/ha	kg/ha
<u>Pangola component</u>					
0% legume	756 a*	4.8 b	54.1 c	36.0 a	385 a
20-40% Siratro	707 a	5.1 ab	57.6 bc	36.0 a	381 a
40-60% Siratro	555 a	5.5 ab	60.5 ab	30.3 a	340 a
15-25% joint vetch	585 a	5.8 a	61.8 a	33.5 a	317 a
<u>Legume component</u>					
20-40% Siratro	319 b	18.0 b	61.8 b	57.0 b	182 b
40-60% Siratro	606 a	16.6 b	61.1 b	115.0 a	394 a
15-25% joint vetch	135 c	23.8 a	75.3 a	32.0 c	95 c
<u>Pangola-legume mixtures</u>					
0% legume	756 b	4.8 c	-	36.0 d	385 c
20-40% Siratro	1026 a	9.1 b	-	93.0 b	563 b
40-60% Siratro	1251 a	11.7 a	-	145.3 a	710 a
15-25% joint vetch	720 b	9.3 b	-	65.5 c	435 bc

* Means within each column, within each component, followed by the same letter are not different at 0.05 level of significance, according to Duncan's Multiple Range Test.

mixture provided a substantial improvement in both quantity and quality of forage produced. When comparing Pangola-Siratro mixtures (Table 16) with Pangola alone, we observed that CP%, DMY, and DOM were roughly twice as high in the mixture, and that the CPY was several fold higher than for Pangola alone. When analyzing the effect of joint vetch on Pangola-legume mixture performance, it can be noticed that neither DMY nor DOM of the mixture were increased, but CP% and CPY of mixtures were twice those from Pangola alone. This is attributed to the very high CP% (23%) in joint vetch. The high CP% of joint vetch compensated for its relatively low DMY.

Third harvest (2 Aug. 1977). The DMY, CP%, IVOMD, CPY, and DOM of Pangola and legume components and Pangola-legume mixtures in the third harvest are shown in Table 17. When 40 to 60% Siratro or joint vetch were present in mixture with Pangola, somewhat higher CP% values were observed for the Pangola component, but grass IVOMD was not affected by different legume contents. The Pangola component DMY, CPY, and DOM were higher in the treatments in which 20 to 40% Siratro and 40 to 60% joint vetch were present.

The higher values for CP%, DMY, CPY, and DOM of Pangola-legume mixtures were obtained when joint vetch comprised 40 to 60% of the mixture, this being a consequence of both higher CP% and IVOMD values of the joint vetch than of the Siratro component of the mixtures (Table 17).

Fourth harvest (20 Sept. 1977). The DMY, CP%, IVOMD, CPY, and DOM of Pangola and legume components and Pangola-legume mixtures in the fourth harvest are shown in Table 18. The CP% of the Pangola component was higher when 70 to 80% joint vetch was present in mixture with the Pangola.

Table 17. Forage DMY, CP%, IVOMD, CPY, and DOM data from the third Pangola-legume harvest (2 Aug. 1977).

Legume content in the mixture	Forage yield and quality measurements				
	DMY	CP	IVOMD	CPY	DOM
	kg/ha	%	%	kg/ha	kg/ha
Pangola component					
0% legume	702 ab*	5.2 b	65.5 a	36.7 b	433 ab
20-40% Siratro	784 a	5.4 b	64.0 a	43.0 ab	472 a
40-60% Siratro	578 b	6.3 ab	63.8 a	36.0 b	344 b
10-15% joint vetch	699 ab	5.2 b	63.2 a	36.8 b	413 ab
40-60% joint vetch	1844 a	6.6 a	63.0 a	56.0 a	489 a
Legume component					
20-40% Siratro	395 bc	13.8 b	59.9 c	53.0 bc	220 bc
40-60% Siratro	600 b	14.2 b	59.9 c	85.0 b	336 b
10-15% joint vetch	45 c	19.5 a	72.6 a	19.0 c	63 c
40-60% joint vetch	1167 a	18.4 a	67.2 b	204.0 a	700 a
Pangola-legume mixtures					
0% legume	702 b	5.2 e	-	36.0 c	433 b
20-40% Siratro	1178 b	8.1 c	-	96.0 bc	692 b
40-60% Siratro	1178 b	10.3 b	-	121.0 b	681 b
10-15% joint vetch	794 b	7.0 d	-	55.0 bc	477 b
40-60% joint vetch	2006 a	12.8 a	-	259.0 a	1190 a

* Means within each column, within each component, followed by the same letter are not different at 0.05 level of significance, according to Duncan's Multiple Range Test.

Table 18. Forage DMY, CP%, IVOMD, CPY, and DOM data from the fourth Pangola-legume harvest (20 Sept. 1977).

Legume content in the mixture	Forage yield and quality measurements				
	DMY	CP	IVOMD	CPY	DOM
	kg/ha	%	%	kg/ha	kg/ha
<u>Pangola component</u>					
0% legume	866 a*	4.4 c	57.1 b	37.1 a	459 a
40-50% Siratro	629 a	4.8 bc	59.5 ab	29.7 ab	349 ab
60-70% Siratro	381 b	5.2 b	61.2 ab	19.9 b	217 b
30-60% joint vetch	569 ab	4.7 bc	59.1 ab	26.2 ab	311 ab
70-80% joint vetch	453 b	6.2 a	59.1 ab	28.5 ab	250 b
5-10% carpon desmodium	755 a	4.7 bc	60.6 ab	35.1 a	419 a
<u>Legume component</u>					
40-50% Siratro	514 b	14.9 a	54.8 a	76.7 b	263 b
60-70% Siratro	798 b	15.3 a	54.9 a	121.8 b	407 b
30-60% joint vetch	512 b	16.7 a	57.2 a	87.6 b	277 b
70-80% joint vetch	1466 a	16.1 a	54.7 a	239.8 a	756 a
5-10% carpon desmodium	60 c	9.1 b	40.6 b	5.7 c	230 c
<u>Pangola-legume mixtures</u>					
0% legume	866 b	4.4 d	-	37.1 c	459 b
40-50% Siratro	1144 b	9.3 c	-	106.4 bc	612 b
60-70% Siratro	1180 b	12.0 ab	-	141.7 b	624 b
30-60% joint vetch	1080 b	10.4 bc	-	113.8 bc	588 b
70-80% joint vetch	1919 a	13.7 a	-	268.2 a	1006 a
5-10% carpon desmodium	815 b	5.0 d	-	40.8 c	443 b

* Means within each column, within each component, followed by the same letter are not different at 0.05 level of significance, according to Duncan's Multiple Range Test.

The Pangola-legume mixtures had higher DMY, CP%, CPY, and DOM yields in the treatments in which Siratro comprised 60 to 70% and joint vetch 70 to 80% of the total mixture. The CP% values obtained in all mixtures, except for Pangola-carpon desmodium, were well above the critical levels required for ruminant animals.

Third Year (1978)

Dry-matter yields (DMY)

Sixth harvest (1 June 1978). In the first harvest in 1978 (sixth harvest) seedbed treatment effects on DMY of Pangola-legume mixtures were not evaluated. The treatments compared in this harvest were: (a) Pangola-Siratro mixture, (b) Pangola-carpon desmodium mixture, and (c) Pangola alone. Verano stylo plots were considered as Pangola alone treatment since there were no plants of this legume growing with Pangola in either 1977 or 1978. The data collected from this harvest were analyzed as a completely random-design experiment, with five replications. Joint vetch was not included in this harvest because seedlings were only 2 to 2.5 cm. Appendix Table 6 shows the analysis of variance for the DMY obtained by each component, total Pangola-legume mixture DMY, and legume percentage in the mixtures. No significant ($P < 0.05$) differences in Pangola component DMY were observed among treatments. Pangola-legume mixture and legume component DMY, however, were higher where Siratro and carpon desmodium were present (Table 19). Siratro and carpon desmodium contributed, respectively, 35 and 31% to the total mixture yield.

Table 19. Pangola, legume, and Pangola-legume DMY in sixth (1 June 1978), and seventh (17 July 1978) harvests.

Plant components	Legume species			
	Siratro	Carpon	Verano [†]	Joint vetch
----- kg/ha -----				
<u>1 June 1978</u>				
Pangola	852 a*	800 a	663 a	-
Legumes	453 a	350 b	0 c	-
Pangola-legume mixtures	1305 a	1150 a	663 a	-
Legume % in mixtures	35 a	31 a	0 c	-
<u>17 July 1978</u>				
Pangola	1428 a	1449 a	1325 a	1358 a
Legumes	680 ab	612 b	0 c	973 a
Grass-legume mixtures	2108 a	2331 a	1325 b	2061 a
Legume % in mixtures	32 a	30 a	0 b	43 a

* Means within each component followed by the same letter are not different at the 0.05 level of significance, according to Duncan's Multiple Range Test.

Seventh harvest (17 July 1978). A seventh harvest was made 6 weeks after the sixth, including the same treatments as in the first plus the Pangola-joint vetch mixture. As for the sixth harvest, no significant ($P < 0.05$) difference was observed for yields of the Pangola component (Table 19 and Appendix Table 6). Legume component DMY were 680, 973, 612, and 0 kg/ha, respectively, in the Siratro, joint vetch, carpon desmodium, and Verano stylo treatments. Pangola-legume mixture DMY in which Siratro, carpon desmodium, and joint vetch were present yielded from 900 to 1000 kg/ha more than Pangola alone (Verano stylo treatment).

Because of the major yield contribution of Siratro and joint vetch in all seedbed preparation treatments in this second summer harvest, seedbed treatment plots were considered main plots and legume species subplots. Therefore, the experimental data collected were analyzed as a split-plot experiment with five main plots (seedbed preparation methods) and two subplots (legumes), with five replications. There was no significant ($P < 0.05$) difference in Pangola component DMY as affected by either seedbed preparation or legume treatments (Table 20 and 21). Legumes, however, had a significant ($P < 0.05$) effect on DMY of legume component and Pangola-legume mixtures, and on legume percentage in the mixtures. Joint vetch DMY and percentage in mixture were twice as high as those of Siratro and resulted in higher DMY for the Pangola-joint vetch mixture (Table 21).

Eighth harvest (21 Sept. 1978). In this harvest seedbed treatment effects on DMY of the Pangola-legume mixtures were not evaluated. The treatments compared in this harvest were mixtures of: (a) Pangola-Siratro, (b) Pangola-joint vetch, (c) Pangola-carpon desmodium, and

Table 20. Analysis of variance for seventh Pangola harvest (17 July 1978).

Plant components	Sources of variation		
	Methods	Legumes	Method x legume interaction
Pangola	ns	ns	ns
Legumes	ns	**	ns
Pangola-legume mixtures	ns	**	ns
Legume % in mixtures	ns	**	ns

** Significant at 1% level.

ns Not significant at 5% level.

Table 21. Effect of the legume species on DMY of the legume component, Pangola-legume mixtures, and legume percentage in the mixtures in the seventh Pangola harvest (17 July 1978).

Plant components	Legume species	
	Siratro	Joint vetch
Pangola	1398 a*	1305 a
Legumes	445 b	940 a
Pangola-legume mixtures	1843 b	2245 a
Legume % in mixtures	23 b	40 b

* Means within rows followed by the same letter are not different at the 0.05 level of significance, according to Duncan's Multiple Range Test.

(d) Pangola alone. The data collected from this harvest were analyzed as a completely random-design experiment, with five replications.

The analysis of variance revealed a significant ($P < 0.05$) difference in DMY of the Pangola-legume mixtures. Pangola-joint vetch mixture DMY was highest, Pangola-carpon desmodium and Pangola-Siratro mixture DMY were intermediate, while Pangola alone showed the lowest DMY (Table 22). Pangola-joint vetch mixtures, which were about 75% joint vetch, yielded almost four times as much as Pangola alone, while Pangola-Siratro and Pangola-carpon desmodium mixtures yielded twice as much as Pangola alone.

Legume effect on Pangola-legume yields in the 1978 growing season

As in the previous growing season (1977), Siratro and joint vetch continued to make high DMY contributions to the Pangola-legume mixtures. Joint vetch and Siratro growth patterns, also tended to be maintained, with Siratro starting its productive phase several weeks earlier than joint vetch. Pangola-joint vetch mixture DMY in the seventh (17 July 1978) and eighth harvests (21 Sept. 1978), however, were twice those obtained by Pangola-Siratro and four times as high as DMY in Pangola alone (Tables 21 and 22).

Here again it should be pointed out that joint vetch, once fully established, will yield twice as much as Siratro at any individual harvest. Joint vetch, however, will end its production of quality forage after setting seed (end of October), and would consequently have a growth cycle about 3 months shorter than Siratro. Considering the length of the period during which these legumes could be utilized under a grazing program, there would be a definite advantage of having a

Table 22. Dry-matter yields (DMY) obtained in the eighth (21 Sept. 1978) harvest.

Treatments	Dry-matter yields
	kg/ha
Pangola-joint vetch	4110 a*
Pangola-Siratro	2836 b
Pangola-carpon	2346 b
Pangola alone	1170 c

* Means in the column followed by the same letter are not different at the 0.05 level of significance, according to Duncan's Multiple Range Test.

Pangola-Siratro mixture rather than a Pangola-joint vetch mixture because while Pangola-joint vetch mixture would provide higher total forage at a given time in the summer, it would provide quality forage for a shorter period than a Pangola-Siratro mixture. Siratro being a perennial will start its productive phase at least 6 weeks before joint vetch and will extend it at least 8 weeks longer than joint vetch without any substantial decrease in either quantity or quality of the forage produced.

The high DMV production capacity and the high quality of the forage produced by joint vetch during mid-summer indicates the potential of this legume for use in hay-making programs. Joint vetch in mixture with Pangola or other tropical grasses could produce substantially higher DMV than any of the grasses alone not fertilized with N. On the other hand, the quality of the forage produced by such mixtures would be several fold higher than that of Pangola grown alone and would make excellent hay. Results from the 1977 growing season showed that in a harvest made on 2 August a Pangola-joint vetch mixture containing an average of 50% joint vetch provided over 2000 kg/ha of DMV containing 13% CP. At the same harvest, Pangola grown alone produced only 702 kg/ha of DMV of forage with a CP content of 5.2% (Table 17).

Legume Persistence

Persistence in 1976 and 1977. Persistence refers to the number of legume plants surviving at the end of the first year after establishment. Siratro and joint vetch had greater numbers of plants in all seedbed treatment plots (Table 23). Very few plants or seedlings of the other legumes were recorded. As previously mentioned, lower than normal late fall (1976)

Table 23. Effect of seedbed preparation and legume species on the number of legume plants found in the Pangola sod 13 and 24 months after seeding.

Legume species	Seedbed preparation methods				
	NT	DS	SD	SS	CSP
----- Number of legume plants per m ² -----					
<u>August 1977[†]</u>					
Siratro	14 cde	17 cde	15 cde	26 bc	11 cde
Centro	2 e	4 e	2 e	6 e	2 e
Joint vetch	5 e	23 bcd	15 cde	34 b	68 a
Verano	2 e	0 e	1 e	2 e	9 de
Carpon	2 e	3 e	1 e	2 e	3 e
<u>August 1978[‡]</u>					
Siratro	12 d*	13 d	15 d	18 d	11 d
Centro	0 d	1 d	1 d	2 d	0 d
Joint vetch	99 c	158 b	164 b	150 b	247 a
Verano	0 d	0 d	0 d	0 d	31 d
Carpon	1 d	2 d	1 d	1 d	2 d

* Means within dates followed by the same letter are not different at the 0.05 level of significance, according to Duncan's Multiple Range Test.

[†] Plants counted between 15 and 17 Aug. 1977.

[‡] Plants counted between 2 and 5 Aug. 1978.

and early winter (1977) temperatures (Table 1) as well as harvesting schedule definitely damaged Verano stylo, while carpon desmodium was severely attacked by root-knot nematodes.

A somewhat larger number of Siratro plants were observed in the SS treatment, which was a consequence of the larger number of seedlings that were present in the previous year (Table 3). When relating the number of Siratro plants persisting in each seedbed preparation method 1 year after seeding, with the respective yields obtained in the same treatments, correlation coefficients (r) of 0.33, 0.91, and 0.96 were calculated, respectively, for groups of values of the first, second, and third summer harvests made in 1977 (Table 24). The low correlation coefficient of $r=0.33$ obtained for the 20 June harvest could have been due to the short active growing period from 1 June, when Siratro began its regrowth until 20 June when it was harvested. In the 2 August and 20 Sept. 1977 harvests the greater number of Siratro plants (SS treatment) were highly correlated with higher Siratro DMY. At the time of the last two harvests Siratro plants were more vigorous, since rainfall and temperatures were more favorable for growth. Thus, under the conditions of this experiment a DMY response was obtained as Siratro plant density increased to the 26 plants per m^2 (SS treatment).

Joint vetch being highly self-regenerating reestablished well in 1977, especially in the CSP treatment (Table 23). The more open sod conditions and the larger plant population in 1976 compared with the other seedbed treatments are believed responsible for the higher seed germination rates. This legume has already been reported to require a higher temperature than other tropical legumes for proper germination. These

Table 24. Number of plants and DMY of Siratro in the different seedbed preparation methods at three different harvests made in the summer of 1977.[†]

Seedbed preparation method	Plant population	Harvest time		
		20 June	2 Aug.	20 Sept.
	plants/m ²	----- kg/ha -----		
NT	14	368	430	626
DS	17	402	392	699
SD	15	432	352	579
SS	26	506	669	827
CSP	11	501	372	537

[†] Plants counted between 15 and 17 Aug. 1977.

results suggest that if early summer production of self-reseeding joint-vetch fields is desired, management practices which remove excessive vegetation and favor higher soil temperatures should be used. Burning the stubble of joint vetch-companion grasses, at the beginning of the growing season (early spring) has been proven to enhance the number of joint vetch seedlings emerging in the summer in self-reseeding joint vetch fields (Tang, 1976). Joint vetch seeds have a high degree of hardseededness which can be partially broken by natural scarification caused by exposure to high soil temperatures which occur in more open grass-sod conditions.

When the number of joint vetch plants was related to the DMY obtained in a harvest made on 20 June 1977, 8 weeks prior to the seedling count, a highly significant correlation coefficient ($r = 0.93$) was obtained (Table 25). Relating this same number of seedlings to the DMY obtained with joint vetch harvested on 2 Aug. 1977, 15 days before the seedling count and on 20 Sept. 1977, 6 weeks after the seedling count, correlation coefficients of 0.93 and 0.96 were obtained (Table 25). These highly positive correlation coefficients show that the number of joint vetch plants per unit of area greatly influenced DMY.

Quite interesting to observe was the difference in DMY obtained with joint vetch and Siratro in two different seedbed treatments at different harvests made during the 1977 growing season (Table 26). Joint vetch in the SS treatment with 34 plants/m² yielded 10, 155, 989, and 200 kg/ha of DMY, respectively, for 20 June, 2 August, 20 September and 21 December; total yield for four harvests was 1354 kg/ha (Table 26).

Table 25. Number of plants and DMY of joint vetch in the different seedbed preparation methods at three different harvests made on the Pangola experiment in the summer of 1977.[†]

Seedbed preparation methods	Plant population	Harvest time		
		20 June	2 Aug.	20 Sept.
	plants/m ²	-----	kg/ha	-----
NT	5	0	33	544
DS	23	28	131	1097
SD	15	0	159	777
SS	34	10	155	989
CSP	68	126	1103	1640

[†] Plants counted between 15 and 17 Aug. 1977.

Dry-matter yields of joint vetch in the CSP treatment, where 68 plants/m² were present, were 126, 1103, 1640, and 220 kg/ha; total DMY was 3,195 kg/ha. These results showed that DMY for the total and individual harvests were substantially higher in the CSP than in the SS treatment. This indicated that 34 plants per m² were insufficient for maximum DMY of joint vetch in addition to the fact that CSP plants germinated sooner than SS plants.

With Siratro, however, it was found that total DMY of the 1977 growing season as well as individual summer-time harvest DMY were only slightly higher in the SS than in the CSP treatment (Table 26). This occurred despite the fact that there were almost three times as many plants per unit of area in the SS as in the CSP treatment. This indicated that plants with a viney type of growth habit (Siratro) may not be affected by plant population as much as erect growing plants (joint vetch).

Persistence in 1978. There were more Siratro and joint vetch plants persisting 2 years after seeding than other legumes (Table 23). Siratro population was little affected by seedbed treatments. Again, the number of joint vetch plants was considerably higher in the CSP treatment than in other treatments. The fact that joint vetch populations were higher in the CSP treatment in the seeding year (1976) and in the second year (1977), probably resulted from seed accumulation in the soil. Seed reserves can build up in the soil because of the hardseededness of joint vetch (Ruelke et al., 1975; Hanna, 1973).

Table 26. Dry-matter yields (DMY) and numbers of Siratro and Joint vetch plants persisting in the Pangola sod in 1977.[†]

Legume species	Seedbed preparation methods	Plant population	Harvest dates				Total of 4 harv.
			20 Jun.	2 Aug.	20 Sept.	21 Dec.	
		plants/m ²	----- kg/ha -----				-----
Siratro	SS	26	506	669	827	210	2212
	CSP	11	501	372	537	200	1610
Joint vetch	SS	34	10	155	989	200	1354
	CSP	68	126	1103	1640	220	3195

[†] Plants counted between 15 and 17 Aug. 1977.

When relating number of joint vetch plants persisting in each seedbed preparation treatment with respective DMV in those treatments, it was noticed that the DMV was lower in the CSP, which had the highest number of plants per m^2 (Table 27). Plants in the CSP treatment plots had thinner stems than plants in treatments with less dense plant populations. It is speculated that plant populations of joint vetch can become too high, due to its high seed production capacity, and thus reduce DMV. The quadratic effect of low yields with 99, higher yields with 150 to 164, and low yields with 247 plants per m^2 supports this speculation.

In table 27 it can be noticed that in 1978, 24 months after seeding, Siratro plant population was quite uniform in all seedbed preparation treatments. These results suggested that intra-specific competition tended to bring the Siratro plant population to an equilibrium of 11 to 18 plants per m^2 from originally higher numbers which had established in 1976 (Table 3). The results also suggested that for the viney Siratro, the number of plants persisting per unit of area is lower than that for an erect type of plant like joint vetch.

Bigalta Limpograss Experiment

Year of Establishment (1976)

Number of legume seedlings established

Six weeks after seeding, there were somewhat fewer Siratro, centro, Verano stylo, and carpon desmodium seedlings in the CSP treatment than in others (Table 28). As with Pangola, these lower germination rates can be attributed to excessively high temperatures and quicker desiccation of the surface 2.5 cm of soil that occurred in this treatment.

Table 27. Dry-matter yields (DMY) and number of Siratro and joint vetch plants persisting in the different seedbed preparation methods in 1978.[†]

Legume species	Seedbed preparation methods	Legume population	DMY
		plants/m ²	kg/ha
Siratro	NT	12	336
	SD	13	335
	DS	15	549
	SS	18	429
	CSP	11	554
Joint vetch	NT	99	670
	SD	158	1178
	DS	164	1274
	SS	150	1036
	CSP	247	638

[†] Plant count was made 15 days after the harvest (17 July 1978).

Table 28. Effect of seedbed preparation treatments and legume species on the number of legume seedlings found in the Bigalta sod 6 weeks after seeding (5 Sept. 1976).

Legume species	Seedbed preparation treatments				
	NT	DS	SD	SS	CSP
	----- Number of seedlings per m ² -----				
Siratro	42 bcde*	76 a	72 a	62 abc	25 de
Centro	33 de	63 abc	40 cde	64 ab	26 de
Joint vetch	34 de	40 cde	37 de	18 e	79 a
Verano	30 de	30 de	41 cde	75 a	49 bcd
Carpon	24 de	22 e	24 e	29 de	28 de

* Means followed by the same letter are not different at the 0.05 level of significance, according to Duncan's Multiple Range Test.

The soil temperatures and moisture contents in the less intensive seed-bed preparation treatments were several degrees lower and had higher moisture contents than the CSP treatment (Appendix Tables 7 and 8). Data in these tables showed that the average daily maximum soil temperature over a period of 14 days following legume seeding was 38° C in the CSP treatment. This temperature and above was shown to reduce germination rates of Siratro, centro, carpon desmodium, and Verano stylo (Table 4). Significantly higher number of joint vetch seedlings were observed in the CSP treatment, evidencing the benefit of higher temperatures in stimulation of germination of this hardseeded legume (Table 4).

Dry-matter yields (DMY) in the first harvest (18 Nov. 1976)

The analysis of variance revealed no significant ($P < 0.05$) difference in DMY of legume component as affected by seedbed treatments (Appendix Table 9). Furthermore, no significant legume effect was revealed for Bigalta component or Bigalta-legume mixture DMY. Seedbed treatments, however, significantly ($P < 0.05$) affected the Bigalta component and Bigalta-legume mixtures, with lower DMY occurring in the CSP treatment (Table 29). This lower DMY was expected since this seedbed treatment retarded the Bigalta growth to the extent that the grass had to reestablish from stems.

Despite the low yields of all legumes in this harvest, significantly higher yields were obtained by joint vetch, followed by Siratro and centro (Table 30). Verano stylo and carpon desmodium, although established by the time of harvest, were below the cutting height used. The extremely aggressive growth characteristics of Bigalta, the frequent

Table 29. Effect of seedbed preparation treatments on DMY of the Bigalta component and the Bigalta-legume mixtures, in the first harvest (18 Nov. 1976).

Plant components	Seedbed preparation treatments				
	NT	DS	SD	SS	CSP
	----- kg/ha -----				
Bigalta	2831 a*	2806 a	2627 a	2481 a	720 b
Bigalta-legume mixtures	2891 a	2813 a	2904 a	2582 a	758 b

* Means in the rows followed by the same letters are not different at the 0.05 level of significance, according to Duncan's Multiple Range Test.

Table 30. Effect of the legume species on DMY of the legume component and legume % in the mixture in the first harvest (18 Nov. 1976).

Plant components	Legume species				
	Siratro	centro	Joint vetch	Verano	carpon
	----- kg/ha -----				
Legumes	99 b*	62 b	214 a	0 c	0 c
	----- % -----				
Legumes in the mixtures	4.0 b	2.4 b	9.7 a	0.0 c	0.0 c

* Means in the rows followed by the same letter are not different at the 0.05 level of significance, according to Duncan's Multiple Range Test.

short-lasting floodings in the summer, and lower than normal temperatures in the fall, are believed to be the main reasons for the poor performance of the legumes in the first harvest.

The results obtained in the late fall harvest, as with Pangola, indicated that seeding of tropical legumes into grass sods by mid-summer as in this study, may not provide any additional increase in the forage produced. This is especially true when considering the poorly drained soil conditions in which Bigalta was growing. Bigalta is well-adapted to these conditions while the legumes used, except for joint vetch and centro which are somewhat tolerant, are all poorly adapted to oxygen-reduced and waterlogged soil conditions.

Effect of legumes on DMY, CP%, CPY, IVOMD, and DOM

There were no significant ($P < 0.05$) differences in the DMY, CP%, IVOMD, CPY, and DOM of the Bigalta component (Table 31). When quality of legume component was compared, Siratro and centro, CP% and IVOMD tended to be higher than joint vetch, while DMY, CPY, and DOM of the legumes were not statistically different. Joint vetch IVOMD was very low at this harvest. Because of its annual nature, little vegetative material was evident at harvest time.

As can be seen from the data in Table 31, the CP% of the Bigalta component and Bigalta-legume mixtures was well below the minimum required for maintenance of ruminant animals. The reason for the low CP% of both Bigalta component and Bigalta-legume mixtures can be attributed to a dilution effect from the high amount of DMY produced by the grass and to the low legume content. The IVOMD of Bigalta, however, was quite good considering that the grass was 4 months old when harvested.

Table 31. Forage DMY, CP%, IVOMD, CPY, and DOM data from the first Bigalta-legume harvest (18 Nov. 1976).

Legume content in the mixtures	Forage yield and quality measurements				
	DMY	CP	IVOMD	CPY	DOM
	kg/ha	%	%	kg/ha	kg/ha
<u>Bigalta component</u>					
0% legume	3089 a*	2.6 a	57.2 a	82.2 a	1698 a
5±2% Siratro	2367 a	2.4 a	56.7 a	56.7 a	1279 a
5±2% centro	2628 a	2.9 a	56.4 a	75.3 a	1415 a
5±2% joint vetch	2903 a	2.7 a	54.9 a	76.9 a	1527 a
<u>Legume component</u>					
5±2% Siratro	130 a	12.3 b	57.4 a	15.0 a	69 a
5±2% centro	141 a	16.9 a	56.9 a	24.0 a	76 a
5±2% joint vetch	168 a	10.1 b	43.5 b	17.0 a	70 a
<u>Bigalta-legume mixtures</u>					
0% legume	3089 a	2.6 b	-	82.0 a	1698 a
5±2% Siratro	2497 a	2.9 b	-	72.0 a	1348 a
5±2% centro	2769 a	3.6 a	-	99.0 a	1491 a
5±2% joint vetch	3070 a	3.1 ab	-	93.0 a	1597 a

* Means within each column, within each component, followed by the same letter are not different at 0.05 level of significance, according to Duncan's Multiple Range Test.

Second Year (1977)

Dry-matter yields (DMY)

Second harvest (16 June 1977). The legume component DMY was low for all legume species (Table 32 and Appendix Table 9). Siratro, which had the highest percentage in the mixture, composed only 7% of the total Bigalta-legume mixture DMY. Bigalta component DMY were lower when Bigalta was growing in mixture with either Siratro, centro, or carpon desmodium. The lower yield of the grass in those treatments can be attributed to inter-specific competition of legumes and Bigalta for nutrients and for space. The low DMY of the legume components is somewhat misleading. Bigalta is a species which possesses a very open type of canopy. As a consequence of the growth habit of this grass, the legumes growing in mixture with it do not tend to climb the stems which results on a quite dense growth of the legume in the understorey of the canopy. When clipping this mixture for yield determination, most of the biomass of the legumes was not removed because it was below the machine cutting height used (10 cm above ground surface).

Third harvest (28 July 1977). The analysis of variance (Appendix Table 9) showed significant ($P < 0.05$) effects of the seedbed treatments on the DMY of the Bigalta component and Bigalta-legume mixtures.

Both the Bigalta component and Bigalta-legume mixtures showed higher DMY in the CSP plots (Table 33). This can be attributed to the higher grass tiller density which resulted as a consequence of the intense seedbed preparation treatment imposed upon these plots in the establishment year. It had been observed that after the CSP treatment, which consisted of disc-harrowing and rototilling the Bigalta

Table 33. Effect of seedbed preparation treatments on DMY of the Bigalta grass component and of the Bigalta-legume mixtures in the third harvest (28 July 1977).

Plant components	Seedbed preparation treatments				
	NT	DS	SD	SS	CSP
	----- kg/ha -----				
Bigalta	930 b*	895 b	909 b	891 b	1158 a
Bigalta-legume mixtures	966 b	983 b	1010 b	967 b	1211 a

* Means within rows followed by the same letter are not different at the 0.05 level of significance, according to Duncan's Multiple Range Test.

sod, a thicker and more vigorous stand reestablishment was obtained probably because of better soil aeration and higher N mineralization. In spite of the low legume component, DMY of the Bigalta component and Bigalta-legume mixtures were higher when centro, joint vetch, Siratro, and carpon desmodium were present (Table 34). Small N fixation and legume residue (leaves, roots, etc.) mineralization in the treatment plots in which legumes were present could have provided some N for Bigalta. This is believed true because Bigalta DMY was lowest in the Verano stylo plots, which had no legume plants in 1977, because of the killing frosts in the winter of 1977.

Fourth harvest (10 Sept. 1977). The analysis of variance revealed a significant ($P < 0.05$) effect of legume treatments on the DMY of the legume component and on the Bigalta-legume mixtures (Appendix Table 9). Legume component and Bigalta-legume mixtures DMY were higher with joint vetch (Table 35). Siratro and centro DMY were about one third, while carpon desmodium yielded about one sixth that of joint vetch.

In this harvest as in the previous one (28 July 1977), the Bigalta component yielded significantly ($P < 0.05$) more in the CSP treatment than in other seedbed preparation treatments (Table 36).

Combined summer harvests in 1977. The analysis of variance showed that seedbed treatments were still influencing the Bigalta component and consequently the Bigalta-legume mixtures (Appendix Table 10). Total summer DMY of Bigalta component and Bigalta-legume mixtures were higher in the CSP treatment (Table 37).

Total summer DMY of the legume components and Bigalta legume mixtures were higher for joint vetch and for Siratro treatment plots

Table 34. Effect of the legume species on the DMY of the legume component, Bigalta-legume mixtures, and legume % in mixtures in the third harvest (28 July 1977).

Plant components	Legume species			
	Siratro	Centro	Joint vetch	Verano
			kg/ha	
Legumes	137 a*	53 bc	105 ab	0 c
Bigalta-legume mixtures	1086 a	1032 a	1085 a	887 b
				1047 a
			%	
Legumes in mixtures	12.3 a	5.0 b	8.4 a	0.0 c
				5.3 b

* Means within rows followed by the same letter are not different at the 0.05 level of significance, according to Duncan's Multiple Range Test.

Table 35. Effect of the legume species on the DMV of the legume component, Bigalta-legume mixtures, and legume % in mixtures in the fourth harvest (10 Sept. 1977).

Plant components	Legume species			
	Siratro	Centro	Joint vetch	Verano
	----- kg/ha -----			
Legumes	227 b*	219 b	639 a	0 c
Bigalta-legume mixtures	1812 b	1846 b	2500 a	1540 b
	----- % -----			
Legumes in the mixtures	13.6 b	10.5 bc	23.9 a	0.0 d

	4.9 cd			

* Means within rows followed by the same letter are not different at the 0.05 level of significance, according to the Duncan's Multiple Range Test.

Table 36. Effect of seedbed preparation treatments on DMY of the Bigalta grass component in the fourth harvest (10 Sept. 1977).

Plant components	Seedbed preparation treatments				
	NT	DS	SD	SS	CSP
	----- kg/ha -----				
Bigalta	1674 b*	1508 b	1602 b	1467 b	2000 a

* Means in the row followed by the same letter are not different at the 0.05 level of significance, according to Duncan's Multiple Range Test.

Table 37. Effect of seedbed preparation treatments on combined 16 July, 28 July, and 10 Sept. 1977 summer DMV of Bigalta component and Bigalta-legume mixtures.

Plant components	Seedbed preparation treatments				CSP
	NT	DS	SD	SS	
	----- kg/ha -----				
Bigalta	4896 b*	4775 b	4871 b	4620 b	5766 a
Bigalta-legume mixtures	5101 b	5197 b	5309 b	5051 b	6103 a

* Means in the rows within each component followed by the same letter are not different at the 0.05 level of significance, according to Duncan's Multiple Range Test.

(Table 38). As can be seen in this table, in spite of the low legume percentage in the mixtures, the best Bigalta-legume combination yielded about 1000 kg/ha more than treatments in which there was no legume.

Winter harvest (21 Dec. 1977). Joint vetch plants were completely mature with most plants already dead at this harvest. The reasons for harvesting at this time was to assure good seed production and reestablishment the following year.

Higher DMV of the Bigalta component were obtained from the CSP treatment when Bigalta was growing in association with Siratro, centro, carpon desmodium, and joint vetch (Table 39 and Appendix Table 9). The higher DMV obtained in the plots where legumes were present and the lower DMV of the Bigalta component in the Verano stylo plots (no legume plants in 1977) indicated that the legumes provided some N to the grass, either directly (N fixation and transfer) or indirectly (through mineralization of plant residues).

Legume effect on Bigalta-legume yields in the 1977 growing season

As can be observed in Fig. 4, the DMV contribution of the legumes to the DMV of the Bigalta-legume mixtures was low in most harvests made in 1977. Siratro, centro, and joint vetch, however, contributed well to the mixture DMV at the 10 September harvest. In the 16 June harvest Siratro, centro, and carpon desmodium, in spite of their low DMV, tended to depress the Bigalta component and Bigalta-legume mixture DMV, which could be a consequence of inter-specific competition for space and/or nutrients.

As stated previously, the relatively poor contribution of legumes in Bigalta (compared with Pangola) were believed to be due to the highly

Table 38. Effect of the legume species on DMY of the legume component, Bigalta-legume mixtures and average legume content of mixtures for the combined 16 June, 28 July, and 10 Sept. 1977 harvests.

Plant components	Legume species			
	Siratro	Centro	Joint vetch	Verano
	----- kg/ha -----			
Legumes	538 ab*	341 bc	756 a	0 d
Bigalta-legume mixtures	5285 b	5145 b	6152 a	5087 b
	----- % -----			
Legume in mixtures	11.0 a	6.4 b	12.7 a	0.0 c
				3.5 bc

* Means within each component, in the rows, followed by the same letter are not different at the 0.05 level of significance, according to Duncan's Multiple Range Test.

Table 39. Effect of seedbed preparation methods and legume species on the DMV of the Bigalta component in the fifth harvest (21 Dec. 1977).

Legume species	Seedbed preparation treatments			
	NT	DS	SD	SS
				CSP
----- kg/ha -----				
Siratro	645 cdef*	621 cdef	595 def	572 def
Centro	620 cdef	823 bcd	735 -cdef	594 def
Joint vetch	588 def	600 def	740 bcde	573 def
Verano	643 cdef	446 ef	696 bcdef	433 f
Carpon	545 def	621 cdef	526 def	501 ef
				1158 a

* Means followed by the same letter are not different at the 0.05 level of significance, according to Duncan's Multiple Range Test.

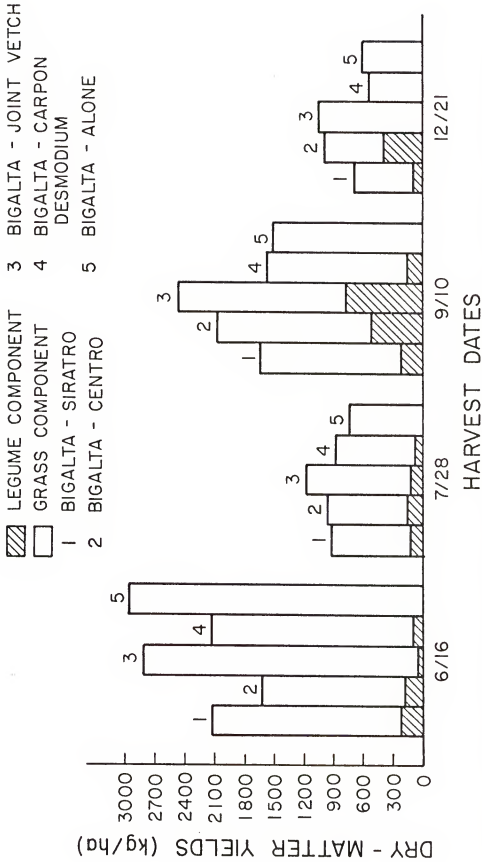


Fig. 4. Effect of legume components on the DMV of the Bigalta component and Bigalta-legume mixtures during 1977.

competitive growth characteristic of this grass species. Bigalta grown alone without N fertilization produced over 5000 kg/ha of DMY as a total of three harvests (Table 38). Another possible reason for the relatively low DMY of the legumes in mixture with Bigalta was the fact that grasses have higher K extraction capacity than legumes (Norris, 1972). The soil under which this experiment was conducted had low K levels (Appendix Table 1). The importance of K in maintaining a balanced grass-legume mixture was reported by several authors (Norris, 1972; Jones, 1966; Whelan and Edwards, 1975). Hall (1974) mentioned that Greenleaf desmodium yields were quite low when growing in mixture with setaria under low soil K. When K levels in the soil were increased by K fertilization, the author observed better yields and persistence of Greenleaf desmodium.

Another speculation that can be made with regard to the high DMY of Bigalta without N fertilization is the possibility of this grass species being able to use NH_4^+ instead of NO_3^- as its N source. Ammonium is the main N end-product of mineralization in poorly drained soils. On the other hand, research has shown that under poorly drained soil conditions the rate of NH_4^+ formation is higher than in better drained soils (Sanchez, 1977). These facts could be the explanation for the high DMY of Bigalta grass in the 1977 growing season, despite the absence of any N fertilizer applications.

Effect of legume on DMY, CP%, CPY, IVOMD, and DOM

Second harvest (16 June 1977). The CP% and IVOMD of the Bigalta component were not significantly ($P < 0.05$) different, regardless of the legume content in the mixture (Table 40). Dry-matter yields, CPY, and DOM, however, were somewhat higher in plots with no legume present.

Table 40. Forage DMY, CP%, IVOMD, CPY, and DOM data from the second Bigalta harvest (16 June 1977).

Legume content in the mixtures	Forage yields and quality measurements				
	DWY	CP	IVOMD	CPY	DOM
	kg/ha	%	%	kg/ha	kg/ha
			<u>Bigalta component</u>		
0% legume	2660 a*	3.5 a	60.9 a	93 a	1555 a
5% Siratro	1868 b	3.7 a	62.5 a	68 ab	1118 b
10% Siratro	2248 ab	3.5 a	61.5 a	77 ab	1325 ab
20-25% Siratro	1893 b	3.7 a	61.8 a	70 ab	1124 b
5% centro	1813 b	3.5 a	63.2 a	63 b	1096 b
			<u>Legume component</u>		
5% Siratro	74 c	14.7 b	57.5 ab	10 c	40 c
10% Siratro	235 b	18.0 a	62.4 a	42 b	138 b
20-25% Siratro	568 a	14.8 b	59.0 ab	84 a	315 a
5% centro	122 bc	16.7 ab	56.3 b	20 bc	64 bc
			<u>Bigalta-legume mixtures</u>		
0% legume	2660 a	3.5 c	-	93 b	1555 a
5% Siratro	1942 b	4.1 bc	-	79 b	1158 a
10% Siratro	2483 ab	4.8 b	-	119 ab	1463 a
20-25% Siratro	2461 ab	6.2 a	-	154 a	1438 a
5% centro	1935 b	4.3 bc	-	84 b	1160 a

* Means within each column, within each component, followed by the same letter are not different at 0.05 level of significance, according to Duncan's Multiple Range Test.

These results could be a consequence of the absence of legume competition for nutrients since DMY of Bigalta were lower when legumes were present.

The CP% and IVOMD of legume components was higher with 10% Siratro. This difference could be due to sampling procedures for chemical analysis with more leaf material included in the 10% Siratro treatment.

The CP% of the 20 to 25% Siratro-Bigalta mixture was near the critical 7% value, below which forage intake is depressed. Even though DMY were higher with zero legume content in the mixture, the highest CPY occurred with 20 to 25% Siratro. The DOM values of the mixtures were not significantly ($P < 0.05$) different among treatments because of the compensating effects of DMY and IVOMD of the mixtures.

Third harvest (28 July 1977). No significant ($P < 0.05$) differences were shown in CP% or in IVOMD of the Bigalta component among treatments with different legume contents (Table 41). Both, however, were higher than in the June 16 harvest.

Significantly higher CP% values were obtained in the Bigalta-legume mixtures where 20% Siratro or 10 to 15% joint vetch were present. The CP% of these mixtures was equal or above the critical 7% value required for maintenance of ruminant animals.

Fourth harvest (10 Sept. 1977). The Bigalta component had somewhat higher CP% when either 20 to 40% Siratro or centro were present in the mixture (Table 42). This difference, however, is of no practical significance since CP% values were very low considering that plants were 6 weeks old when harvested. The reasons for the low CP% values of Bigalta can be attributed to a dilution effect due to the high dry-matter yields.

Table 41. Forage DMY, CP%, IVOMD, CPY, and DOM data from the third Bigalta-legume harvest (28 July 1977).

Legume content in the mixtures	Forage yields and quality measurements				
	DMY	CP	IVOMD	CPY	DOM
	kg/ha	%	%	kg/ha	kg/ha
			<u>Bigalta component</u>		
0% legume	804 ab*	5.1 a	64.7 a	41 b	496 abc
5% Siratro	1100 ab	5.2 a	65.2 a	57 ab	675 ab
20% Siratro	763 b	5.3 a	64.3 ab	40 b	460 c
5% centro	1127 a	5.8 a	64.8 a	65 a	684 a
5% joint vetch	855 ab	5.3 a	60.5 ab	46 ab	387 abc
10-15% joint vetch	831 ab	5.2 a	60.5 ab	43 b	478 bc
			<u>Legume component</u>		
5% Siratro	51 c	21.4 a	67.9 a	11 c	31 c
20% Siratro	220 a	21.1 a	64.6 a	44 a	130 a
5% centro	62 c	19.8 b	59.8 b	12 c	34 c
5% joint vetch	34 c	21.0 a	64.9 a	7 c	21 c
10-15% joint vetch	142 b	17.5 b	53.2 c	25 b	71 b
			<u>Bigalta-legume mixtures</u>		
0% legume	804 b	5.1 d	-	41 c	496 b
5% Siratro	1152 ab	5.9 c	-	66 ab	706 ab
20% Siratro	983 ab	8.6 a	-	85 a	591 ab
5% centro	1189 a	6.6 bc	-	78 ab	718 a
5% joint vetch	889 ab	5.9 c	-	54 bc	507 ab
10-15% joint vetch	973 ab	7.0 b	-	68 ab	549 ab

* Means within each column, within each component, followed by the same letter are not different at 0.05 level of significance, according to Duncan's Multiple Range Test.

Table 42. Forage DMY, CP%, IVOMD, CPY, and DOM data from the fourth Bigalta-legume harvest (10 Sept. 1977).

Legume content in the mixtures	Forage yields and quality measurements				
	DMY	CP	IVOMD	CPY	DOM
	kg/ha	%	%	kg/ha	kg/ha
<u>Bigalta component</u>					
0% legume	1240 a	3.2 b	56.1 a	40.5 a	668 a
20-40% Siratro	1328 a	4.1 a	59.6 a	51.9 a	755 a
10-20% centro	1364 a	3.4 b	57.3 a	46.4 a	733 a
20-40% centro	1665 a	4.1 a	58.4 a	67.7 a	918 a
20-40% joint vetch	1963 a	3.6 b	59.9 a	73.3 a	1113 a
5-10% carpon desmodium	1926 a	3.5 b	60.0 a	66.1 a	1108 a
<u>Legume component</u>					
20-40% Siratro	631 b	15.6 bc	53.9 b	98.0 b	331 c
10-20% centro	218 c	17.5 ab	55.2 b	38.6 c	112 c
20-40% centro	761 ab	18.9 a	53.8 b	144.0 a	387 b
20-40% joint vetch	841 a	18.6 a	63.3 a	156.1 a	500 a
5-10% carpon desmodium	167 c	12.9 c	45.6 c	21.9 cd	72 c
<u>Bigalta-legume mixtures</u>					
0% legume	1240 c	3.2 c	-	40.5 d	668 c
20-40% Siratro	1959 bc	8.1 a	-	150.4 b	1086 abc
10-20% centro	1583 c	5.5 b	-	85.0 cd	845 bc
20-40% centro	2417 ab	8.9 a	-	211.6 a	1305 ab
20-40% joint vetch	2805 a	8.4 a	-	229.5 a	1613 a
5-10% carpon desmodium	2093 abc	4.2 bc	-	88.1 cd	1172 abc

* Means within each column, within each component, followed by the same letter are not different at the 0.05 level of significance, according to Duncan's Multiple Range Test.

Joint vetch composing 20 to 40% of the total mixture yield resulted in the highest legume component DMY, CP%, IVOMD, CPY, and DOM. It was also observed that carpon desmodium had the lowest CP% and a very low IVOMD.

Bigalta-legume mixtures in which either 20 to 40% centro or joint vetch were present provided higher DMY, CP%, CPY, and DOM than the other mixtures. These results suggested that more than 20% legume needed to be present in mixture with Bigalta in order to bring the CP% of the mixture to an acceptable (over 7%) value. Mixtures in which either 10 to 20% centro or 5 to 10% carpon desmodium were present resulted in CP% values only slightly higher than those obtained by the Bigalta grown alone (Table 42).

Third Year (1978)

Dry-matter yields (DMY)

Sixth harvest (1 June 1978). The treatments compared in this harvest were: (a) Bigalta-carpon desmodium, (b) Bigalta-centro, and (c) Bigalta alone. Verano stylo plots were used as the Bigalta alone treatment since no plants of this legume were present in mixture with Bigalta in either the 1977 or 1978 growing seasons. The data collected from this harvest were analyzed as a completely random-design experiment with five replications. As can be noted, neither Siratro plots, because of low plant population (Table 45), nor joint vetch plots, because of the low height (2 to 2.5 cm) of the numerous seedlings were harvested at this occasion.

Bigalta, legume component, and Bigalta-legume mixture DMY were higher in the Bigalta-centro and Bigalta-carpon desmodium mixtures than in the Bigalta alone treatment (Table 43). In spite of the relatively low legume content in the mixtures, the Bigalta component yielded about 1000 kg/ha more DMY when growing in association with either centro or carpon desmodium than when grown alone. These results could be a consequence of at least two factors. First, centro and carpon desmodium were two of the most productive legumes throughout the 1977 growing season, which could have provided more organic material (fallen leaves, nodules, etc.) to the system. This organic material, once mineralized during late spring (warmer temperatures and more moisture) could have provided more available N and caused the higher Bigalta component DMY observed. Legume leaf fall has often been mentioned as being an important source of N for the grass in grass-legume systems (Whitney et al., 1967). Furthermore, soil analyses revealed higher number of free-living organisms in the centro and carpon desmodium plots compared with other plots. With the presence of higher number of free-living organisms including organic-matter decomposers, the rate of N mineralization could have been increased.

Seventh harvest (17 July 1978). The second harvest in the 1978 season was made 6 weeks after the first. The treatments compared in this harvest were: (a) Bigalta-centro, (b) Bigalta-carpon desmodium, (b) Bigalta-joint vetch, and (d) Bigalta alone. The data collected from this harvest were analyzed as a completely random-designed experiment, with five replications.

The analysis of variance for DMY obtained in this harvest revealed no significant ($P < 0.05$) difference for Bigalta component or Bigalta-

Table 43. Bigalta, legume, and Bigalta-legume DMY in sixth (1 June 1978) and seventh (17 July 1978) harvests.

Plant components	Legume species			
	Centro	Carpon	Verano [†]	Joint vetch
	----- kg/ha -----			
	<u>1 June 1978</u>			
Bigalta	2619 a*	2813 a	1629 b	-
Legumes	243 a	341 a	0 b	-
Bigalta-legume mixtures	2862 a	3154 a	1629 b	-
Legume % in mixtures	9 a	11 a	0 b	-
	<u>17 July 1978</u>			
Bigalta	2820 a	2810 a	2890 a	2550 a
Legumes	200 b	170 b	0 c	447 a
Bigalta-legume mixtures	2964 a	2880 a	2890 a	2997 a
Legume % in mixtures	7 b	6 b	0 c	17 a

* Means within each component followed by the same letter are not different at the 0.05 level of significance, according to Duncan's Multiple Range Test.

[†] Verano plots were considered as Bigalta alone since there were no legume plants present.

legume mixtures due to treatment effects (Appendix Table 11). The probable reason for this was that Bigalta in mixtures with centro and carpon had already utilized the more rapidly mineralized N, while the mineralized N in the grass alone plots was not available until after the first harvest. It is doubtful that any significant quantities of N produced during the 6 weeks between harvests were available to the grass component.

Table 43 shows that, except for joint vetch, DMY of all other legumes were very low. These results show that there is definite need for more information on the multiple factors involved in the persistence of the legume component in grass-legume mixtures. Intra, and inter-specific competition, Rhizobium-legume relationships, climatic factors, and soil-borne insects are some of those factors.

Eighth harvest (21 Sept. 1978). In the third summer harvest made in the 1978 growing season, seedbed treatment effects on the DMY of the Bigalta-legume mixtures were not studied. The treatments compared in this harvest were mixtures of: (a) Bigalta-centro, (b) Bigalta-carpon desmodium, (c) Bigalta-joint vetch, and (d) Bigalta alone. The data collected from this harvest were analyzed as a completely random-design experiment, with five replications.

The analysis of variance revealed significant ($P < 0.05$) difference among DMY of the Bigalta-legume mixtures. Bigalta-legume mixtures with either centro, joint vetch, or carpon desmodium produced about twice as much DMY than Bigalta grown alone (Table 44). Visual estimations of botanical composition of the mixtures indicated that joint vetch, centro, and carpon desmodium were contributing with about 60 to 70%, 40 to 50%, and 20 to 25%, respectively, to the total DMY of the mixtures.

Table 44. Dry-matter yields (DMY) obtained in the eighth harvest (21 Sept. 1978).

Treatments	Dry-matter yields
	----- kg/ha -----
Bigalta-centro mixture	4315 a*
Bigalta-carpon mixture	3720 a
Bigalta-joint vetch mixture	4732 a
Bigalta alone	2351 b

* Means in the column followed by the same letter are not different at the 0.05 level of significance, according to Duncan's Multiple Range Test.

Dry-matter yields obtained in any of the mixtures can be considered extremely good. Also, the contribution of the legumes (based on estimated percentages) was the highest during the 3-year-period of study. The results also indicated that centro and joint vetch definitely are the legumes better adapted to the oxygen-reduced conditions of the experimental area. The results further suggested that the approximately 10-week cutting interval between the second and third 1978 harvests might have favored legume component yields compared with 6-week cutting intervals.

Legume persistence in 1977 and 1978

A very uniform number of Siratro, centro, and carpon desmodium plants were found in all seedbed treatments in both 1977 and 1978 (Table 45). Joint vetch, however, had significantly ($P < 0.05$) higher number of plants in the CSP treatment in 1977 and in 1978. In 1978, even though the number of joint vetch plants was higher in the CSP treatment, a relatively high number of plants was also found in the other seedbed treatments. Verano stylo had no surviving plants in the 1977 and 1978 growing seasons. The extremely low temperatures occurred early in 1977 (Table 1) killed all Verano plants.

The higher number of joint vetch plants present in the CSP treatment is most probably a result of seed reserve build-up in the soil, since joint vetch had always (1976 and 1977) produced higher amount of seeds in this seedbed treatment. Seed reserve build-up was also believed responsible for the high number of joint vetch plants in the other seedbed treatments in 1978.

Table 45. Effect of seedbed preparation and legume species on the number of legume plants found in the Bigalta sod 13 and 24 months after seeding.

Legume species	Seedbed preparation treatments				
	NT	DS	SD	SS	CSP
----- Number of legume plants per m ² -----					
<u>August 1977[†]</u>					
Siratiro	6 bc	8 bc	9 bc	6 bc	7 bc
Centro	6 bc	8 bc	6 bc	10 bc	8 bc
Joint vetch	8 bc	11 bc	13 bc	12 bc	38 a
Verano	0 c	0 c	0 c	0 c	0 c
Carpon	7 bc	6 bc	8 bc	6 bc	12 bc
<u>August 1978[‡]</u>					
Siratiro	2 cd*	3 cd	4 cd	3 cd	2 cd
Centro	6 c	60 c	65 c	8 c	5 cd
Joint vetch	65 b	64 b	55 b	60 b	84 a
Verano	0 d	0 d	0 d	0 d	0 d
Carpon	6 c	5 cd	8 c	6 c	7 c

* Means within dates followed by the same letter are not different at the 0.05 level of significance, according to Duncan's Multiple Range Test.

[†] Plants counted between 15 and 17 Aug. 1977.

[‡] Plants counted between 2 and 5 Aug. 1978.

The number of plants of centro and carpon desmodium was about the same in 1977 and in 1978, but the number of Siratro plants was substantially lower in 1978 than in 1977. These results clearly indicated what had been already pointed out previously in this discussion: Centro and carpon desmodium are relatively better adapted to the poorly drained soil conditions of the experimental area than Siratro.

The seedbed treatments affected the establishment of all legumes in 1976 (seeding year), but this influence was lessened as time progressed. In the first (1977) and second (1978) years after establishment, all legumes, except Siratro and joint vetch, had about the same number of plants in all seedbed preparation treatments.

Joint vetch population dynamics in Pangola and Bigalta were similar. The amount of seeds produced during the previous year and the number of seeds in reserve in the soil, determined the number of seedlings germinating during the growing season of the following year. The number of seedlings germinating were also affected by the environmental factors (soil moisture, soil temperature), and by the hardseededness of this legume.

Centro, a perennial legume species, produced no seed during the period of 1976 to 1978 and after a marked population reduction between 1976 and 1977 tended to reach a stabilized plant population by 1978. Carpon desmodium (also a perennial) plants were too weak in 1976 to produce any seeds, but produced some seed in the fall of 1977. In the fall of 1978 seed production was assessed as good. Based on this observation, there is the distinct possibility of an increase in the plant population of carpon desmodium in the next growing season.

SUMMARY AND CONCLUSIONS

Two field studies were conducted at the Agricultural Research Center (ARC), Fort Pierce, Florida, from July 1976 to September 1978.

The main purpose of the research was to determine the effect of several seedbed preparation methods on establishment and persistence of five tropical legumes in two tropical grass sods. An additional objective was to determine the effect of inclusion of the legumes into the grass sods on quantity and quality of the forage produced by the mixtures.

Seedbed preparation methods studied were: no tillage, light disking of the sod followed by legume seed broadcast and cultipacking, legume seed broadcast followed by disking and cultipacking, sod-seeding with a 'Zip-seeder' machine, and complete seedbed preparation method. The legume species used in this study were: 'Siratro' (Macroptilium atropurpureum (DC.) Urb.), centro (Centrosema pubescens Benth.), joint vetch (Aeschynomene americana L.), 'Verano' Caribbean stylo (Stylosanthes hamata (L.) Taub.), and 'Florida' carpon desmodium (Desmodium heterocarpon (L.) DC.). The treatments were arranged in a split-plot design with five replications. The seedbed preparation methods constituted the main plots while the legume species were the subplots. The two experimental areas used were 3-year-old swards of 'Pangola' digitgrass (Digitaria decumbens Stent.) and 'Bigalta' limpo-grass (Hemarthria altissima (Poir.) Stapf et C. E. Hubbard).

The comparative establishment of the legumes was evaluated by seedling counts made 3 and 6 weeks after seeding. In both Pangola and Bigalta experiments, Siratro, centro, carpon desmodium, and Verano stylo had somewhat higher numbers of seedlings established in the sod-seeding treatment, and relatively low numbers of seedlings in the complete seedbed preparation method. Joint vetch seedling numbers, however, were somewhat higher in the complete seedbed preparation treatment. Excessively high soil temperatures occurring in the complete seedbed preparation treatment were the most probable cause of the germination depression of some of the legumes, while joint vetch was apparently favored by the higher soil temperatures. Previous research had shown this to be true.

The number of legume plants persisting in the Pangola experiment, in the second and third growing seasons after establishment, was very low for centro, carpon desmodium, and Verano stylo. The number of Siratro plants, however, was quite high and joint vetch reestablished itself due to its very good seed production during late fall of each year. The extremely low temperatures that occurred during the winter of 1977 as well as nematode infestations are believed to have been the main reasons why there were low number of persisting plants of carpon desmodium, centro, and Verano stylo in the years subsequent to establishment. The total dry-matter produced and the quality of the forage obtained during the second and third growing seasons (summers of 1977 and 1978) in the Pangola-Siratro and Pangola-joint vetch mixtures were substantially higher than those obtained with any other Pangola-legume mixture.

In the Bigalta experiment, there were higher numbers of persisting plants of joint vetch, centro, and carpon desmodium than of other legumes. Their ability to withstand frequent flooding and the absence of root-knot nematodes (which attacks carpon desmodium) in the Bigalta field are the most probable reasons for these results.

Results from the present study suggested that Siratro and joint vetch were better adapted and more compatible for use in mixtures with Pangola digitgrass. The better performance of these legumes with Pangola compared with Bigalta, can be attributed in part, to the relatively better drained conditions found in the Pangola field.

The high seed production capacity of joint vetch resulted in reliable reestablishment year after year of this annual. Its very high dry-matter yield production capacity once well established, together with its excellent quality (comparable to alfalfa in terms of crude protein content) suggests that it deserves more attention and study than it has received. Another favorable characteristic of joint vetch is its high tolerance to frequently flooded soil conditions which are a rule rather than an exception in most south Florida pastures during the summer season.

Siratro which is a perennial has an advantage over the annual joint vetch, provided both are growing in moderately drained soils. Siratro in the present study started its productive phase about 6 weeks earlier and extended it approximately 2 months later than joint vetch. If both species were growing under conditions characterized by poorly drained soil conditions, however, Siratro would be in definite disadvantage.

Carpon desmodium if planted in areas free of root-knot nematodes (Meloidogyne incognita) can make a substantial contribution to the quantity and quality of forage produced by grass-legume mixtures.

Verano stylo, due to its low resistance to the winter temperatures and its late flowering characteristics mainly in the establishment year, will probably be of limited potential for use in Florida. Its use in Florida might be further limited by the fact that early frosts that are likely to occur in late fall might not allow this legume to flower and set seeds, consequently reducing its persistence.

APPENDIX

Appendix Table 1. Analysis of soil from Pangola and Bigalta experimental areas.[†]

Sampling dates	pH(H ₂ O)	Soil analyses										
		P	K	Ca	Mg	Cu	Fe	Al	Mn	Zn	Na	Mo
		----- ppm -----										
		<u>Pangola</u>										
5/18/77	6.4	18.8	16.0	298.0	56.4	6.8	32.8	24.0	106.4	7.2	54.8	5.6
4/ 4/78	6.3	15.5	11.0	364.0	41.2	5.8	31.4	20.0	100.0	9.9	47.2	0.04
8/18/78	6.1	13.9	16.0	232.0	20.8	5.6	17.2	16.0	92.5	5.6	16.0	0.02
<u>Bigalta</u>												
5/18/77	6.5	31.8	6.0	524.0	148.0	4.6	32.8	36.0	89.2	8.4	16.7	1.2
4/ 4/78	6.3	20.1	7.0	480.0	46.8	3.3	31.6	30.0	81.0	9.9	52.8	0.04
8/18/78	6.3	21.9	16.0	404.0	32.8	3.2	18.8	28.0	82.5	5.3	16.0	0.02

[†] All elements are extractable (double-acid, 1:4 dilution factor) values.

Appendix Table 2. Soil moisture content at 2.5 and 5.0 cm sampling depth for the complete seedbed (CSP) and light discing (DS) treatment plots of the Pangola experiment.

Date of sampling	Seedbed preparation method	Depth of sampling		
		0 - 2.5 cm	2.5 - 5.0 cm	
		-----	Moisture %	-----
7/26/76 [†]	DS	8.0	9.0	
	CSP	2.2	5.4	
8/3/76 [‡]	DS	9.0	7.0	
	CSP	6.0	7.0	

[†] Soil samples and moisture content determinations were made in mid-afternoon, 24 hours after occurrence of 6.35 mm of rainfall.

[‡] Samples taken 24 hours after 12.7 mm of rainfall.

Appendix Table 3. Diurnal soil temperature readings of the soil surface for the complete seedbed preparation (CSP) treatment and at 2.0 cm below the soil surface for the light discing (DS) treatment during 14 days after seeding of the legumes in the Pangola experiment.

Days after seeding	Soil Temperatures [†]					
	Maximum		Minimum		Mean	
	CSP	DS	CSP	DS	CSP	DS
	----- ° C -----					
1	50	36	35	28	43	32
2	59	40	35	28	47	34
3	53	38	34	27	43	32
4	42	35	31	28	36	31
5	40	34	29	27	35	30
6	38	34	34	29	36	32
7	42	35	29	28	35	32
8	39	35	30	27	34	32
9	39	34	32	27	36	30
10	53	32	34	28	43	30
11	40	35	33	27	36	30
13	35	32	32	30	33	31
14	37	34	33	28	35	31
Avg.	43	35	32	28	38	31

[†] Temperatures were recorded from 9 a.m. in the morning to 5 p.m. in the afternoon.

Appendix Table 4. Analyses of variance for DMV of the first five harvests of Pangola-legume mixtures.

Plant components	Sources of variation		
	Methods	Legumes	Method x legume interaction
<u>18 Nov. 1976</u>			
Pangola	**	ns	ns
Legumes	**	**	ns
Pangola-legume mixtures	**	ns	ns
Legume % in mixtures	**	**	*
<u>20 June 1977</u>			
Pangola	ns	ns	ns
Legumes	ns	**	ns
Pangola-legume mixtures	ns	**	ns
Legume % in mixtures	ns	**	ns
<u>2 Aug. 1977</u>			
Pangola	ns	ns	ns
Legumes	**	**	**
Pangola-legume mixtures	**	**	**
Legume % in mixtures	**	**	**
<u>20 Sept. 1977</u>			
Pangola	*	**	ns
Legumes	*	**	ns
Pangola-legume mixtures	**	**	ns
Legume % in mixtures	ns	**	ns
<u>21 Dec. 1977</u>			
Pangola	ns	*	ns
Legumes	ns	**	ns
Pangola-legume mixtures	ns	**	ns
Legume % in mixtures	ns	**	ns

* Significant at 5% level.

** Significant at 1% level.

ns Not significant at 5% level.

Appendix Table 5. Analysis of variance of combined 1977 summer DMY of Pangola and legume components, Pangola-legume mixtures and average legume content of mixtures during the summer.[†]

Plant components	Source of variation		
	Methods	Legumes	Method x legume interaction
Pangola	ns	**	ns
Legumes	**	**	**
Pangola-legume mixtures	**	**	**
Legume % in mixtures	ns	**	ns

[†] Combined 20 June, 2 August, and 20 Sept. 1977 harvests.

** Significant at 5% level.

ns Not significant at 5% level.

Appendix Table 6. Analysis of variance for DMV obtained in the sixth (1 June 1978) and seventh (17 July 1978) Pangola harvests.

Plant components	Harvest	
	1 June 1978	17 July 1978
---- Statistical significance ----		
Pangola	*	ns
Legumes	**	**
Pangola-legume mixtures	**	**
Legume % in mixtures	**	**

* Significant at 5% level.

** Significant at 1% level.

ns Not significant at 5% level.

Appendix Table 7. Soil moisture content at 2.5 and 5.0 cm sampling depth for the complete seedbed preparation (CSP) and for the light discing treatment (DS) plots of the Bigalta experiment.

Date of sampling	Seedbed preparation method	Depth of sampling	
		0 - 2.5 cm	2.5 - 5.0 cm
----- Moisture % -----			
7/29/76 [†]	DS	7.0	8.0
	CSP	5.0	8.0
8/3/76 [‡]	DS	12.0	9.0
	CSP	10.0	9.0

[†] Soil samples and moisture content determinations were made by mid-afternoon, 24 hours after a 6.35 mm of rainfall

[‡] Samples taken after a 12.7 mm rainfall.

Appendix Table 8. Diurnal soil temperature readings of the soil surface for the complete seedbed preparation (CSP) treatment and at 2.0 cm below the soil surface for the light discing (DS) treatment during 14 days after seeding of the legumes in the Bigalta experiment.

Days after seeding	Soil temperatures [†]					
	Maximum		Minimum		Mean	
	CSP	DS	CSP	DS	CSP	DS
	----- ° C -----					
1	42	33	33	27	37	31
2	48	35	33	28	40	31
3	44	33	31	27	37	30
4	34	30	30	27	32	28
5	34	30	28	27	31	28
6	36	32	32	28	34	30
7	37	33	28	28	32	30
8	36	33	29	27	33	30
9	38	33	32	27	35	30
10	42	33	33	27	37	30
11	39	34	32	27	35	30
12	35	32	31	28	33	30
13	34	32	30	29	32	30
14	37	33	31	28	34	30
Avg.	38	33	31	28	34	30

[†] Temperatures were recorded from 9 am in the morning until 5 pm in the afternoon.

Appendix Table 9. Analyses of variance for DMY of the first five harvests of Bigalta-legume mixtures.

Plant components	Sources of variation		
	Methods	Legumes	Method x legume interaction
<u>18 Nov. 1976</u>			
Bigalta	**	ns	ns
Legumes	ns	**	ns
Bigalta-legume mixtures	**	ns	ns
Legume % in mixtures	ns	**	ns
<u>16 June 1977</u>			
Bigalta	ns	**	ns
Legumes	ns	**	ns
Bigalta-legume mixtures	ns	ns	ns
Legume % in mixtures	ns	**	ns
<u>28 July 1977</u>			
Bigalta	**	ns	ns
Legumes	ns	**	ns
Bigalta-legume mixtures	**	*	ns
Legume % in mixtures	ns	**	ns
<u>10 Sept. 1977</u>			
Bigalta	*	ns	ns
Legumes	ns	**	ns
Bigalta-legume mixtures	ns	**	ns
Legume % in mixtures	ns	**	ns
<u>21 Dec. 1977</u>			
Bigalta	**	**	*
Legumes	ns	**	ns
Bigalta-legume mixtures	**	**	ns
Legume % in mixtures	ns	**	ns

* Significant at 5% level.

** Significant at 1% level.

ns Not significant at 5% level.

Appendix Table 10. Analysis of variance for DMY of *Bigalra* and legume components *Bigalra*-legume mixtures and average legume content of mixtures during the summer.[†]

Plant components	Sources of variation		
	Methods	Legumes	Method x legume interaction
<i>Bigalra</i>	**	ns	ns
Legumes	ns	**	ns
<i>Bigalra</i> -legume mixtures	**	**	ns
Legume % in mixtures	ns	**	ns

[†] Combined 16 June, 28 July, and 10 Sept. 1977 harvests.

** Significant at 1% level.

ns Not significant at 5% level.

Appendix Table 11. Analyses of variance for DMY obtained in the sixth (1 June 1978) and seventh (17 July 1978) Bigalta harvests.

Plant components	Harvests	
	1 June 1978	17 July 1978
	----- Statistical significance -----	
Bigalta	**	ns
Legumes	**	**
Bigalta-legume mixtures	**	ns
Legume % in mixtures	**	**

** Significant at 1% level.

ns Not significant at 5% level.

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BIOGRAPHICAL SKETCH

Darci Tercio Gomes was born in Tapera, Rio Grande do Sul, on 14 August 1946. From March 1967 to December 1970 he attended the Universidade Federal do Rio Grande do Sul, receiving the degree of Engenheiro Agrônomo. In March of 1971 he started the graduate school at the same University and received the degree of Master of Science with a major in agronomy in January of 1973.

In May of 1973 he joined the staff of the Instituto de Pesquisas Agropecuarias do Leste (IPEAL) to work with tropical forage crops. In 1974 he was contracted by the Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA), and in 1975 came to the University of Florida to pursue the Doctor of Philosophy degree in agronomy, under the sponsorship of EMBRAPA.

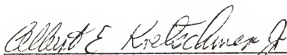
The author is a member of the Sociedade Brasileira de Zootecnia, and Gamma Sigma Delta (Florida Chapter).

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Elmo B. Whitty, Chairman
Professor of Agronomy

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Albert E. Kretschmer, Jr. Co-Chairman
Professor of Agronomy

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.



William G. Blue
Professor of Soil Science

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.



Charles E. Dean
Professor of Agronomy

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.



Otto C. Ruelke
Professor of Agronomy

This dissertation was submitted to the Graduate Faculty of the College of Agriculture and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

December 1978



Dean, College of Agriculture

Dean, Graduate School